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An International Journal

Official Organ of
The American Phytopathological Society

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PHYTOPATHOLOGY

VOLUME 21 NUMBER 5

MAY, 1931

STUDIES OF THE FUNGICIDAL ACTION OF CERTAIN DUSTS AND SPRAYS IN THE CONTROL OF APPLE SCAB[1]

J. M. HAMILTON

INTRODUCTION

Investigations of the effectiveness of fungicides in the control of diseases of orchard fruits have consisted chiefly of field spraying and dusting work and laboratory studies. While these types of experimentation have yielded very valuable results, each has certain important limitations. In orchard work the environment must be accepted without control and the complexity of variables frequently prevents adequate analysis of results. Furthermore, years of experimentation may elapse before conditions suitable for certain phases of the work are encountered. In laboratory experiments, on the other hand, certain factors of environment may be very accurately controlled. However, the conditions are likely to be so different from those encountered in nature that an interpretation of results obtained from laboratory work can be applied to field conditions only with due reservations. It has seemed desirable in work with apple scab to supplement the field and laboratory studies with greenhouse experiments, in which the fungicides could be applied at will to plants on which the disease was induced by inoculation under partly controlled conditions. This work was begun by Keitt and Jones (29),[2] who developed the technique and conducted preliminary studies. The writer has continued this line of work with special attention to a study of the comparative efficiency of various sulphur fungicides and the relation of certain factors of the environment to their effectiveness.

No attempt will be made to review the extensive literature relative to the fungicidal action of sulphur and its compounds, as this seems to have been sufficiently accomplished in the papers of Windisch (60), Barker,

[1] Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

Grateful acknowledgments are made to Dr. G. W. Keitt, at whose suggestion these studies were undertaken, for his kind suggestions and criticisms throughout the investigation and preparation of the manuscript.

[2] Reference is made by number (italic) to "Literature Cited," p. 520.

Gimingham, and Wiltshire (2), Doran (10), Young (61), Vogt (54), Barker (3, 4), Roach and Glynne (44), Young and Williams (62), Goldsworthy (17), Goodwin and Martin (24, 25), Williams and Young (57, 58), Marsh (34), Martin (36), Roach (45), Goodwin, Martin, and Salmon (21) and others. In view of the great number of contributions on the specific use of sulphur for apple-scab control and the limitations encountered in an interpretation of much of the data, a general review of this literature in the present paper appears to be unwarranted. Studies of the epidemiology and control of apple scab and of the ascigerous stage of *Venturia inaequalis* Cke. and Wint. are reported in papers of Keitt and Jones (29) and Wilson (59) and in literature cited by them. As seems necessary, references will be made to the more pertinent work in the appropriate connections in the body of the paper.

GREENHOUSE AND FIELD STUDIES—MATERIALS[3]

The materials used are listed and briefly described as follows:

Sulphur Dusts

Super-sulfodust. A proprietary dusting sulphur prepared by the Niagara Sprayer and Chemical Co., Inc. It is guaranteed to contain not less than 92 per cent of pure sulphur and not more than 8 per cent of inert ingredients. The sulphur has a fineness to permit 98 per cent to pass through a 300-mesh screen.

Sulphur-arsenate dust. Prepared by thoroughly mixing 10 parts by weight of powdered arsenate of lead with 90 parts of Super-sulfodust.

Kolodust. A proprietary Bentonite-sulphur dust prepared by the Niagara Sprayer and Chemical Co., Inc., guaranteed to contain not less than 90 per cent of sulphur and not more than 10 per cent of inert ingredients. It is a mixture of Bentonite-sulphur (colloidal) with finely ground dusting sulphur which has a fineness to permit 98 per cent to pass through a 300-mesh screen.

Kolotex. A proprietary Bentonite-sulphur dust containing arsenate of lead prepared by the Niagara Sprayer and Chemical Co., Inc.,

[3] Acknowledgments are made to the following companies for the preparation and donation of materials used in this investigation:

Niagara Sprayer and Chemical Co., Inc., Middleport, New York.
Stauffer Chemical Company of Texas, Houston, Texas.
Koppers Company Laboratories, Mellon Institute, Pittsburgh, Pennsylvania.
Pacific Gas and Electric Company, San Francisco, California.
Cream City Chemical Works, Milwaukee, Wisconsin.
Standard Oil Company of Indiana, Whiting, Indiana.
Bayer-Semesan Company, Inc., Wilmington, Delaware.
Corona Chemical Division, Pittsburgh Plate Glass Co., Milwaukee, Wisconsin.

guaranteed to contain not less than 77 per cent of sulphur and not less than 10 per cent of arsenate of lead. The sulphur is a mixture of Bentonite-sulphur (colloidal) with finely ground dusting sulphur which has a fineness to permit 98 per cent to pass through a 300-mesh screen. The arsenate of lead was guaranteed to contain not less than 1.95 per cent of its own weight of total arsenic (as metallic) and not over 0.5 per cent of total arsenic in water-soluble forms (as metallic).

Bentonite-sulphur. Prepared by the Niagara Sprayer and Chemical Co., Inc. Bentonite-sulphur is the finely divided (colloidal) superactive ingredient of the Niagara Kolo Dusts. It is prepared by fusing sulphur into bentonite, with which it has been previously blended.

Pomodust. A proprietary 90–10 sulphur-arsenate dusting mixture prepared by the Niagara Sprayer and Chemical Co., Inc., guaranteed to contain not less than 87 per cent of pure sulphur and not less than 10 per cent of arsenate of lead. The sulphur has a fineness to permit 98 per cent to pass through a 300-mesh screen. The arsenate of lead was guaranteed to contain not less than 1.95 per cent of its own weight of total arsenic (as metallic) and not over 0.5 per cent of the total arsenic in water-soluble forms (as metallic).

Sublimed sulphur. Anchor Brand Velvet Flowers of Sulphur, the sulphur component of "oxidized sulphur" prepared by the Stauffer Chemical Company of Texas. It has a Chancel test of 76.2° C. It runs 95 to 99 per cent through a 200-mesh screen and is 100 per cent pure.

Oxidized sulphur. A proprietary "oxidizing sulphur," prepared by the Stauffer Chemical Company of Texas. This dusting mixture was composed of sublimed sulphur, 96 per cent; potassium permanganate, 2 per cent; and a catalyst, 2 per cent.

Ferrox sulphur dust. A ground sulphur dust with size of particle averaging 5 microns, prepared by the Koppers Company Laboratories from Ferrox flotation sulphur, a by-product in the purification of manufactured gas.

Wettable Sulphur Preparations[4]

Ferrox flotation sulphur. Wettable sulphur paste with size of particles averaging 3 microns, a by-product in the purification of manufactured gas, containing from 2 to 6 per cent iron oxide in a very finely divided state. Prepared by the Koppers Company Laboratories.

[4] The concentration of the washed and unwashed flotation sulphur sprays used in these experiments was calculated on dry-sulphur basis. These sulphurs do not differ from one another in so far as characteristics of the sulphur particle are concerned.

Thylox flotation sulphur (unwashed). Wettable sulphur paste with size of particles averaging 3 microns, a by-product in the purification of manufactured gas from which all the impurities (mainly small percentages of sodium thiosulphate and sodium thiocyanate) have not been washed. Prepared by the Koppers Company Laboratories.

Gray flotation sulphur. Wettable sulphur paste with size of particles averaging 3 microns, a by-product in the purification of manufactured gas containing nickel. Prepared by the Koppers Company Laboratories.

P. G. & E. sulphur paste. Wettable sulphur paste known as black gashouse sulphur in California and of the same type as Gray flotation sulphur. Prepared by the Pacific Gas and Electric Company.

Koloform. A proprietary wettable Bentonite-sulphur dust prepared by the Niagara Sprayer and Chemical Co., Inc., guaranteed to contain 54 per cent of sulphur and not more than 46 per cent of inert ingredients.

Sprays Containing Lime-sulphur

Lime-sulphur (liquid). A commercial product prepared by Cream City Chemical Works. The specific gravity varied little from 1.8602.

Lime-sulphur, aluminum sulphate mixture (Kelsall's spray). Aluminum sulphate, $3\frac{1}{2}$ pounds to 40 gallons; lime-sulphur, 1–40; and calcium arsenate, $\frac{3}{4}$ pound to 40 gallons. (Brittain, Kelsall, and Hockey (6).)

Arsenical Compounds

Arsenate of lead. A commercial powdered acid arsenate of lead, prepared by the Niagara Sprayer and Chemical Co., Inc., guaranteed to contain not less than 98 per cent of lead arsenate, not less than 30 per cent of total arsenic oxide (As_2O_5), and not over 0.5 per cent of the total arsenic in water-soluble forms (as metallic).

Calcium arsenate. A commercial powdered calcium arsenate product, prepared by the Niagara Sprayer and Chemical Co., Inc., guaranteed to contain not less than 70 per cent of tri-calcium arsenate, not less than 40 per cent of total arsenic oxide (As_2O_5), and not over 0.5 per cent of the total arsenic in water-soluble forms (as metallic).

Tri-lead arsenate. A basic lead arsenic product, made by the Sherwin-Williams Company, Cleveland, Ohio, guaranteed to contain not less than 25 per cent arsenic oxide and not over 1 per cent of the total arsenic in water-soluble forms (as metallic).

Copper Fungicides

Bordeaux mixture 4–4–50. Chemically pure hydrated lime and copper sulphate were used. No correction was made for use of hydrated instead of stone lime in the composition of the spray.

Copper-lime-arsenate dust. A mixture composed of 10 per cent by weight of finely ground anhydrous cupric sulphate, 80 per cent of hydrated lime, and 10 per cent of powdered arsenate of lead.

Emulsified Oils

L20. A white oil emulsion of the inert type. Prepared by the Standard Oil Company of Indiana.

L202. A white oil emulsion with a lower degree of stability and a higher percentage of oil than held by L20. Prepared by the Standard Oil Company of Indiana.

L205. A white oil emulsion, L20, containing a form of sulphur. Prepared by the Standard Oil Company of Indiana.

Mercurial Compounds

K–1–CB. A proprietary organic ethyl mercury chloride compound with water-soluble and volatile toxic material. Prepared by the Bayer-Semesan Company, Inc.

K–1–GB. A proprietary organic ethyl mercury chloride compound with water-soluble and comparatively nonvolatile toxic material. Prepared by the Bayer-Semesan Company, Inc.

117. A proprietary organic hexamethylene bichloride of mercury compound on a talc base. Prepared by the Corona Chemical Division, Pittsburgh Plate Glass Company.

117C. A proprietary organic hexamethylene bichloride of mercury compound on a bentonite-mixture base. Prepared by the Corona Chemical Division, Pittsburgh Plate Glass Company.

117E. A proprietary organic hexamethylene bichloride of mercury compound on a bentonite-mixture base. The material is acid and contains free mercuric chloride. Prepared by the Corona Chemical Division, Pittsburgh Plate Glass Company.

118. A pure monobasic mercury compound without a base. Prepared by the Corona Chemical Division, Pittsburgh Plate Glass Company.

Other Materials

Calcium monosulphide U.S.P. Contained approximately 68 per cent calcium sulphide.

Casein-lime. "Kayso," a proprietary product obtained from the Griffiths Milk Products Company, Chicago, Illinois.

Lime. The hydrated and stone lime were C.P. products. The hydrated lime was used unless otherwise stated. The stone lime contained 98 per cent calcium oxide.

Soft soaps. Twentieth Century Soap and XXX Cork Tile Soap, made by Theo. B. Robertson Products Co., Inc., Chicago, Illinois. The 20th Century Soap is a neutral sodium soft soap containing 0.5 per cent alkaline salts but no free caustic alkali. The XXX Cork Tile Soap is a neutral potassium soft soap containing 0.12 per cent alkaline salts but no free caustic alkaline.

Other chemicals. The chemicals used other than the above were C.P. products. Distilled water was used in the preparation of all the fungicidal treatments made in the greenhouse unless otherwise stated.

APPARATUS AND METHOD

The moist chamber (Fig. 1) devised by Keitt and Jones (29) was used to accomplish spore germination and infection at the desired temperatures. Two potted Wealthy apple trees (one to three years old) with an average of two to three twigs each (Fig. 2) were used for each experiment. In all cases, unless otherwise stated, the trees were naturally infected by means of ascosporic inoculum of *Venturia inaequalis*. Overwintered apple leaves, bearing abundant perithecia which had been brought to maturity under suitable conditions of temperature and moisture, were placed on wire-net trays above the experimental trees. Ascospores were discharged, and their abundance was observed by microscopic examination of Petri plates exposed in representative situations in the chamber. Fungicidal treatments were made at suitable intervals before or after inoculation by means of a 2½-gallon "Hudson Sprayer" or a small garden hand duster. All moist treatments supplementary to those given during the period of inoculation were provided by placing the plants in the moist chamber at the same temperature used during the inoculation period. After removal from the moist chamber the trees were placed in the greenhouse, unless otherwise stated. After an adequate incubation period for the disease to develop, records were made of the number of lesions on each infected leaf per twig. The maximum number of lesions recorded on any one leaf was 100, regardless of any greater amount of infection, as counts could not be made with satisfactory accuracy if more than 100 lesions were present and a quantitative record above 100 would add little value to the data. Only the infection on the upper surface of the leaves was considered.

EXPERIMENTS IN WHICH THE FUNGICIDES WERE APPLIED BEFORE INFECTION

The widely accepted theory that underlies the application of most fungicides to plants in foliage is that effective treatments must precede

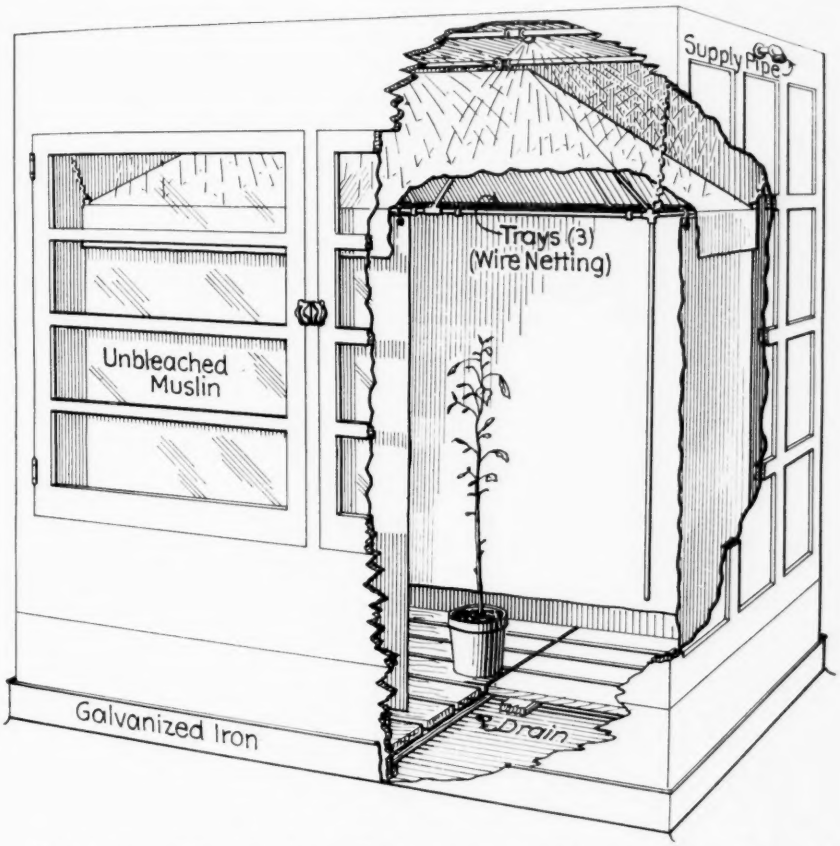

FIG. 1. Inoculation chamber. The temperature in the inner chamber is regulated by the temperature of the water sprayed upon it. The desired temperature is achieved by mixing hot and cold water from supplies kept at suitable constant temperatures. A uniform saturated humidity is assured by wetting the inside of the inner chamber before using. The cloth parts of the inner chamber are washed and sterilized at frequent intervals to kill microorganisms which attack the cloth and might give off gases which inhibit infection.

and prevent infection. Attention has been focused, therefore, upon some of the phenomena of fungicidal effectiveness when applications were made before the infection period began.

The data reported by Keitt and Jones (29) on the relation of time of application and temperature to the effectiveness of certain fungicides in the control of *Venturia inaequalis* in the greenhouse under controlled conditions show that sulphur treatments gave excellent control when the applications were made 24 hours before inoculation, while Bordeaux mixture gave almost no control under the same conditions. Greaney (26), in an

FIG. 2. A. Section of greenhouse showing potted plants used in experimental work. B. Typical potted Wealthy apple trees used in inoculation experiments. C. Turntable used to obtain uniformity of treatment of trees in inoculation and washing experiments.

TABLE 1.—*Relations of certain fungicidal applications to infection of Wealthy apple leaves by ascospores of Venturia inaequalis*

Fungicidal treatment		Inoc. chamber		Final results averaged per twig		
Series, date, and fungicide[a]	Time applied	Temp.	Period in	Leaves infected	Max. lesions on one leaf	
		°C.	Hrs.	No.	No.	Rel. No.
Series 1, 4–20–26						
Untreated		6	32	1.7	8.5	100
L-S 1–40 + AL 1–50	24 hrs. before inoc. began[b]	6	32	0.0	0.0	0
S-Ars. dust 90–10	"	6	32	0.0	0.0	0
Series 2, 4–24–26						
Untreated		7	42	2.7	13.5	100
L-S 1–40 + AL 1–50	24 hrs. before inoc. began[b]	7	42	0.0	0.0	0
S-Ars. dust 90–10	"	7	42	0.0	0.0	0
Series 3, 4–27–26						
Untreated		7	32	1.7	7.0	100
L-S 1–40 + AL 1–50	24 hrs. before inoc. began[b]	7	32	0.0	0.0	0
S-Ars. dust 90–10	"	7	32	0.0	0.0	0
Series 4, 5–7–26						
Untreated		10	27	3.3	40.0	100
L-S 1–40 + AL 1–50	24 hrs. before inoc. began	10	27	0.0	0.0	0
S-Ars. dust 90–10	"	10	27	0.0	0.0	0
Series 5, 5–11–26						
Untreated		10	27	4.0	16.5	100
L-S 1–40 + AL 1–50	24 hrs. before inoc. began	10	27	0.0	0.0	0
S-Ars. dust 90–10	"	10	27	0.0	0.0	0
Series 6, 5–28–26						
Untreated		20	24	2.8	19.1	100
L-S 1–40 + AL 1–50	12 hrs. after inoc. began	20	12	0.0	0.0	0
S-Ars. dust 90–10	"	20	12	1.0	2.0	11
L-S 1–40 + AL 1–50	24 hrs. after inoc. began	20	24	0.0	0.0	0
S-Ars. dust 90–10	"	20	24	3.0	14.6	76

TABLE 1.—(*Continued*)

Fungicidal treatment		Inoc. chamber		Final results averaged per twig		
Series, date, and fungicide[a]	Time applied	Temp.	Period in	Leaves infected	Max. lesions on one leaf	
		°C.	Hrs.	No.	No.	Rel. No.
Series 7, 6–2–26						
Untreated		20	24	2.7	18.7	100
L-S 1–40 + AL 1–50	12 hrs. after inoc. began	20	12	0.0	0.0	0
S-Ars. dust 90–10	"	20	12	0.0	0.0	0
L-S 1–40 + AL 1–50	24 hrs. after inoc. began	20	24	1.0	1.0	5
S-Ars. dust 90–10	"	20	24	2.0	13.2	71
Series 8, 4–11–27						
Untreated		6	45	3.0	15.7	100
L-S 1–40 + AL 1–50	24 hrs. before inoc. began[b]	6	45	0.0	0.0	0
S-Ars. dust 90–10	"	6	45	0.0	0.0	0
L-S 1–40 + AL 1–50	45 hrs. after inoc. began	6	45	0.0	0.0	0
S-Ars. dust 90–10	"	6	45	2.5	10.5	67
Series 9, 4–14–27						
Untreated		6	45	2.0	7.3	100
L-S 1–40 + AL 1–50	24 hrs. before inoc. began[b]	6	45	0.0	0.0	0
S-Ars. dust 90–10	"	6	45	0.0	0.0	0
L-S 1–40 + AL 1–50	45 hrs. after inoc. began	6	45	0.0	0.0	0
S-Ars. dust 90–10	"	6	45	1.0	6.0	82
Series 10, 4–18–27						
Untreated		7	15	1.8	5.0	100
L-S 1–40 + AL 1–50	15 hrs. after inoc. began	7	15	0.0	0.0	0
S-Ars. dust 90–10	"	7	15	3.0	8.2	164
Untreated		7	20	3.5	31.5	100
L-S 1–40 + AL 1–50	20 hrs. after inoc. began	7	20	0.5	3.5	11
S-Ars. dust 90–10	"	7	20	3.5	13.2	42
Untreated		7	25	4.5	71.7	100
L-S 1–40 + AL 1–50	25 hrs. after inoc. began	7	25	0.5	5.5	8
S-Ars. dust 90–10	"	7	25	2.2	14.5	20

TABLE 1.—(*Continued*)

Fungicidal treatment		Inoc. chamber		Final results averaged per twig		
Series, date, and fungicide[a]	Time applied	Temp.	Period in	Leaves infected	Max. lesions on one leaf	
		°C.	Hrs.	No.	No.	Rel. No.
Untreated		7	30	4.2	90.2	100
L-S 1–40 + AL 1–50	30 hrs after inoc. began	7	30	0.0	0.0	0
S-Ars. dust 90–10	"	7	30	3.2	31.5	35
Untreated		7	40	3.4	43.0	100
L-S 1–40 + AL 1–50	40 hrs. after inoc. began	7	40	0.0	0.0	0
S-Ars. dust 90–10	"	7	40	4.2	54.8	127
Series 11,[c] 5–20–27						
L-S 1–40 + AL 1–50	24 hrs. before inoc. began[b]	12	45	0.0	0.0	0
S-Ars. dust 90–10	"	12	45	0.5	0.5	1
Untreated		12	15	5.0	37.8	100
L-S 1–40 + AL 1–50	15 hrs. after inoc. began	12	15	1.0	1.0	3
S-Ars. dust 90–10	"	12	15	2.8	10.4	28
Untreated		12	30	5.0	71.2	100
L-S 1–40 + AL 1–50	30 hrs. after inoc. began	12	30	2.0	8.6	12
S-Ars. dust 90–10	"	12	30	4.0	34.0	48
Untreated		12	45	3.6	72.7	100
L-S 1–40 + AL 1–50	45 hrs. after inoc. began	12	45	2.0	10.5	14
S-Ars. dust 90–10	"	12	45	4.3	62.6	86
Series 12, 5–6–27						
L-S 1–40 + AL 1–50	24 hrs. before inoc. began[b]	10	45	0.0	0.0	0
S-Ars. dust 90–10	"	10	45	0.0	0.0	0
Untreated		10	15	4.0	20.4	100
L-S 1–40 + AL 1–50 (wet)[d]	15 hrs. after inoc. began	10	15	0.0	0.0	0
L-S 1–40 + AL 1–50 (dry)[e]	"	10	15	0.0	0.0	0
S-Ars. dust 90–10 (wet)	"	10	15	0.0	0.0	0
S-Ars. dust 90–10 (dry)	"	10	15	2.7	8.3	41
Untreated		10	30	4.6	33.2	100
L-S 1–40 + AL 1–50 (wet)	30 hrs. after inoc. began	10	30	0.0	0.0	0
L-S 1–40 + AL 1–50 (dry)	"	10	30	2.5	4.0	12

TABLE 1.—(*Continued*)

Fungicidal treatment		Inoc. chamber		Final results averaged per twig		
Series, date, and fungicide[a]	Time applied	Temp.	Period in	Leaves infected	Max. lesions on one leaf	
		°C.	Hrs.	No.	No.	Rel. No.
S-Ars. dust 90–10 (wet)	"	10	30	2.3	12.2	37
S-Ars. dust 90–10 (dry)	"	10	30	3.2	28.2	85
Untreated		10	45	4.0	50.2	100
L-S 1–40 + AL 1–50 (wet)	45 hrs. after inoc. began	10	45	0.0	0.0	0
L-S 1–40 + AL 1–50 (dry)	"	10	45	0.0	0.0	0
S-Ars. dust 90–10 (wet)	"	10	45	3.3	8.7	17
S-Ars. dust 90–10 (dry)	"	10	45	4.3	25.3	50
L-S 1–40 + AL 1–50 (dry)	4 days after inoc. began	10	45	1.0	11.0	22
S-Ars. dust 90–10 (dry)	"	10	45	4.0	37.5	75
L-S 1–40 + AL 1–50 (dry)	8 days after inoc. began	10	45	4.3	33.0	66
S-Ars. dust 90–10 (dry)	"	10	45	4.7	64.6	129
Series 13, 5–1–27						
L-S 1–40 + AL 1–50	24 hrs. before inoc. began[b]	10	45	0.0	0.0	0
S-Ars. dust 90–10	"	10	45	0.0	0.0	0
Untreated		10	15	3.7	22.0	100
L-S 1–40 + AL 1–50 (wet)[d]	15 hrs. after inoc. began	10	15	0.0	0.0	0
L-S 1–40 + AL 1–50 (dry)[e]	"	10	15	1.0	3.7	17
S-Ars. dust 90–10 (wet)	"	10	15	1.8	4.2	19
S-Ars. dust 90–10 (dry)	"	10	15	2.3	9.5	43
Untreated		10	30	4.6	81.4	100
L-S 1–40 + AL 1–50 (wet)	30 hrs. after inoc. began	10	30	0.0	0.0	0
L-S 1–40 + AL 1–50 (dry)	"	10	30	0.5	0.5	1
S-Ars. dust 90–10 (wet)	"	10	30	3.5	14.5	18
S-Ars. dust 90–10 (dry)	"	10	30	3.0	34.5	42
Untreated		10	45	5.0	92.2	100
L-S 1–40 + AL 1–50 (wet)	45 hrs. after inoc. began	10	45	2.3	17.6	19
L-S 1–40 + AL 1–50 (dry)	"	10	45	2.6	9.6	10
S-Ars. dust 90–10 (wet)	"	10	45	3.7	41.2	45
S-Ars. dust 90–10 (dry)	"	10	45	4.8	88.5	96
L-S 1–40 + AL 1–50 (dry)	4 days after inoc. began	10	45	2.3	24.3	26

TABLE 1.—(*Continued*)

Fungicidal treatment		Inoc. chamber		Final results averaged per twig		
Series, date and fungicide[a]	Time applied	Temp.	Period in	Leaves infected	Max. lesions on one leaf	
		°C.	Hrs.	No.	No.	Rel. No.
S-Ars. dust 90–10 (dry)	"	10	45	3.3	37.3	40
L-S 1–40 + AL 1–50 (dry)	8 days after inoc. began	10	45	5.2	53.2	58
S-Ars. dust 90–10 (dry)		10	45	2.8	31.7	34
Series 14, 5–25–27						
L-S 1–40	24 hrs. before inoc. began[b]	14	30	0.0	0.0	0
L-S 1–40 + AL 1–50	"	14	30	0.0	0.0	0
Aerated L-S 1–40	"	14	30	0.0	0.0	0
S-Ars. dust 90–10	"	14	30	0.0	0.0	0
Koloform	"	14	30	0.0	0.0	0
Untreated		14	30	3.6	18.2	100
L-S 1–40 (wet)[d]	30 hrs. after inoc. began	14	30	0.0	0.0	0
L-S 1–40 (dry)[e]	"	14	30	1.0	1.0	6
L-S 1–40 + AL 1–50 (wet)	"	14	30	0.0	0.0	0
L-S 1–40 + AL 1–50 (dry)	"	14	30	1.5	1.5	8
Aerated L-S 1–40 (wet)	"	14	30	3.0	13.3	73
Aerated L-S 1–40 (dry)	"	14	30	3.0	10.8	59
S-Ars. dust 90–10 (wet)	"	14	30	1.0	1.5	8
S-Ars. dust 90–10 (dry)	"	14	30	3.5	20.0	110
Koloform (wet)	"	14	30	3.0	21.3	117
Koloform (dry)	"	14	30	2.7	13.0	71
Series 15,[c] 5–28–27						
L-S 1–40	Before inoc. began	14	30	0.0	0.0	0
L-S 1–40 + AL 1–50	"	14	30	0.0	0.0	0
Aerated L-S 1–40	"	14	30	0.0	0.0	0
S-Ars. dust 90–10	"	14	30	0.0	0.0	0
Koloform	"	14	30	0.0	0.0	0
Untreated		14	30	5.5	53.5	100
L-S 1–40	30 hrs. after inoc. began	14	30	0.0	0.0	0
L-S 1–40 + AL 1–50	"	14	30	0.0	0.0	0

TABLE 1.—(*Continued*)

Fungicidal treatment		Inoc. chamber		Final results averaged per twig		
Series, date and fungicide[a]	Time applied	Temp.	Period in	Leaves infected	Max. lesions on one leaf	
		°C.	Hrs.	No.	No.	Rel. No.
Aerated L-S 1–40	"	14	30	2.5	52.5	98
S-Ars. dust 90–10	"	14	30	3.0	17.5	35
Koloform	"	14	30	4.0	79.0	148
Series 16, 3–3–28						
Untreated		2.5	72	2.3	22.0	100
Kolotex	Just before inoc. began	2.5	72	0.0	0.0	0
Series 17, 5–3–28						
Untreated		20	40	4.8	51.8	100
Kolodust	Just before inoc. began	20	40	0.0	0.0	0
BM 4–4–50	"	20	40	2.0	1.8	3
L20 2%	"	20	40	0.0	0.0	0
L202 2%	"	20	40	0.7	1.5	3
L205 2%	"	20	40	0.0	0.0	0
Series 18, 5–18–28						
Untreated		10	40	4.1	32.0	100
Kolodust	Just before inoc. began	10	40	0.0	0.0	0
BM 4–4–50	"	10	40	1.0	2.3	7
L20 2%	"	10	40	0.0	0.0	0
L202 2%	"	10	40	0.0	0.0	0
L205 2%	"	10	40	0.0	0.0	0

[a] L-S = Commercial liquid lime-sulphur. AL = Commercial powdered arsenate of lead. S-Ars. dust = Sulphur-arsenate dust, 90–10. BM = Bordeaux mixture. L20 and L202 = Emulsified oils. L205 = L20 containing a form of sulphur.

[b] The treated trees were subjected to 12 hours in moist chamber, ending 6 hours before inoculation.

[c] The series was incubated outside after treatment.

[d] The trees were subjected to 15 hours in moist chamber at 10° C. after treatment.

[e] The trees were removed after treatment to Grh 20–25° C.

investigation of the effectiveness of sulphur dusts against some cereal rusts under controlled greenhouse conditions, obtained good control when the treatments were applied 12 days before inoculation, provided the plants were kept dry until inoculated.

Excellent control of apple scab was obtained by the present writer from applications made before inoculation, using various sulphur preparations (aerated lime-sulphur 1–40 included), Bordeaux mixture, and certain oil emulsions (Table 1, Ser. 1–5, 8, 9, 11–18). The sulphur fungicides were effective when applied just before inoculation or 24 hours before inoculation. Certain sulphur fungicides and Bordeaux mixture may protect rapidly growing foliage from infection when applied more than 24 hours before inoculation (Table 7). The noteworthy point is that, under the conditions of this investigation, where applications were made before the infection periods began, the plants were not subjected to loss of protection through rain or washing treatments; all of the materials named gave essentially full protection. It is obvious, therefore, that scab is very easy to control during one period favorable for infection, if the fungicidal agent is not washed off. However, the situation is quite different when experimental conditions are modified (1) to test the comparative effectiveness of materials when applied after infection has started, and (2) to subject the protective materials to washing treatments before the experimental plants are inoculated.

EXPERIMENTS IN WHICH THE FUNGICIDES WERE APPLIED AFTER INFECTION

The most critical time for the control of *Venturia inaequalis* under orchard conditions is during the period of rapid expansion of susceptible host parts early in the season, when environmental factors are likely to be more favorable for infection than later in the year. Early infections provide an early secondary inoculum which, particularly in the case of sepal infection, may result in severe scabbing of the fruit. The rapid expansion of host parts in the preblossom period makes adequate protection very difficult and expensive to maintain. A fungicide which would be effective when applied shortly after infection would offer distinct advantages for scab control in emergencies arising when adequate protection could not be provided before the infection period. An investigation of the effectiveness of sprays or dusts applied after inoculation for the control of *V. inaequalis* was begun by Keitt and Jones (29) in the greenhouse under controlled conditions. This work has been continued by the present writer with special attention to a study of the comparative efficiency of various sulphur fungicides and the relation of temperature and moisture to their effectiveness.

Keitt and Jones (29) found a suggestion of the inhibition of *Venturia inaequalis* under controlled conditions when treatments followed infection

TABLE 2.—*Effectiveness of certain fungicidal treatments applied after infection of Wealthy apple leaves by ascospores of Venturia inaequalis*

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 1, 3–22–28									
Untreated	23	46	0	0	0	3.0	16.0	100	100
Oxidized sulphur	23	46	0	0	0	1.7	7.6	48	41
Sublimed sulphur	23	46	0	0	0	1.5	8.0	50	33
$KMnO_4$ 2%	23	46	0	0	0	1.0	1.0	6	3
Ferrox sulphur dust	23	46	0	0	0	1.7	9.2	58	34
Kolotex	23	46	0	0	0	2.0	6.0	38	24
L202 2%	23	46	0	0	0	1.0	3.3	21	12
L205 2%	23	46	0	0	0	0.0	0.0	0	0
L202 2% + Kolodust 8–50	23	46	0	0	0	0.5	2.0	13	7
BM 4–4–50	23	46	0	0	0	2.0	4.6	29	21
L-S 1–40 + AL 1–50	23	46	0	0	0	1.0	1.0	6	7
Series 2, 4–6–28									
Untreated	10	46	0	0	0	5.4	34.1	100	100
Oxidized sulphur	10	46	0	0	0	3.8	18.2	53	29
Sublimed sulphur	10	46	0	0	0	6.0	18.3	54	58
Kolodust	10	46	0	0	0	3.2	15.0	44	30
Kolotex	10	46	0	0	0	4.4	23.8	70	43
Super-sulfodust	10	46	0	0	0	4.3	25.0	73	58
P. G. & E. sulphur paste 5–50	10	46	0	0	0	4.5	15.6	46	33
Ferrox sulphur dust	10	46	0	0	0	3.4	26.8	79	60
Ferrox sulphur paste 5–50	10	46	0	0	0	5.5	34.7	102	103
Ferrox sulphur paste 5–50 + AL 1–50	10	46	0	0	0	3.8	26.0	76	45
L-S 1–40	10	46	0	0	0	0.0	0.0	0	0
L-S 1–40 + AL 1–50	10	46	0	0	0	0.7	1.3	4	1
AL 1–50	10	46	0	0	0	4.6	16.4	48	38
L205 2%	10	46	0	0	0	1.4	3.6	11	9
BM 4–4–50	10	46	0	0	0	3.0	7.0	21	14

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 3, 4–9–28									
Untreated	10	72	0	0	16	4.2	26.0	100	100
Kolodust	10	72	0	0	16	4.0	33.6	129	110
BM 4–4–50	10	72	0	0	16	3.2	11.0	42	51
AL 1–50	10	72	0	0	16	3.8	12.4	48	54
L202 2%	10	72	0	0	16	4.0	13.2	51	71
L205 2%	10	72	0	0	16	2.0	5.0	19	15
L202 2% + Kolodust 8–50	10	72	0	0	16	1.0	6.0	23	9
L-S 1–40	10	72	0	0	16	1.2	3.7	14	5
Series 4, 4–17–28									
Untreated	10	65	0	24	5	6.2	85.5	100	100
Oxidized sulphur	10	65	0	24	5	5.2	44.0	51	35
Sublimed sulphur	10	65	0	24	5	6.0	56.7	66	58
$KMnO_4$ 2%	10	65	0	24	5	1.0	2.0	2	1
Kolotex	10	65	0	24	5	6.0	44.8	52	42
L202 2%	10	65	0	24	5	5.8	12.2	14	14
L205 2%	10	65	0	24	5	4.2	14.2	17	8
L202 2% + Kolotex 8–50	10	65	0	24	5	3.2	5.2	6	5
L-S 1–40 + AL 1–50	10	65	0	24	5	1.2	2.5	3	1
Series 5, 4–18–28									
Untreated	10	64	0	0	24	5.2	45.4	100	100
Oxidized sulphur	10	64	0	0	24	4.3	54.0	119	98
Kolodust	10	64	0	0	24	4.3	36.0	79	50
Ferrox sulphur dust	10	64	0	0	24	3.3	42.0	93	61
Ferrox sulphur paste 5–50	10	64	0	0	24	3.3	38.0	84	97
P. G. & E. sulphur paste 5–50	10	64	0	0	24	4.0	38.6	85	60
Precipitated sulphur	10	64	0	0	24	3.7	35.0	77	58
C-L-Ars. dust 10–80–10	10	64	0	0	24	4.3	70.3	155	123

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 6, 5–12–28									
Untreated	12	48	0	24	13	3.3	28.3	100	100
Kolotex	12	48	0	24	13	0.3	0.3	1	0
NaOH N/14	12	48	0	24	13	0.7	0.7	2	3
Lime 3–50	12	48	0	24	13	2.3	12.6	45	27
Soft soap 1%[c]	12	48	0	24	13	2.3	20.6	73	41
Series 7, 5–19–28									
Untreated	15	42	30	24	18	5.2	64.5	100	100
L-S 1–40	15	42	30	24	18	1.3	9.6	15	8
L-S 1–40 + AL 1–50	15	42	30	24	18	1.0	7.5	12	6
K-l-CB 2–50	15	42	30	24	18	2.6	12.3	19	24
K-l-GB 2–50	15	42	30	24	18	3.3	26.6	41	60
L-S 1–40	15	42	52	1	18	2.5	11.0	17	15
L-S 1–40 + AL 1–50	15	42	52	1	18	0.5	0.5	1	0
K-l-CB 2–50	15	42	52	1	18	3.5	24.5	38	58
K-l-GB 2–50	15	42	52	1	18	4.5	49.0	76	103
Series 8, 6–2–28									
Untreated	17	48	32	3	12	5.2	86.2	100	100
L-S 1–40	17	48	32	3	12	3.0	42.7	50	33
L-S 1–40 + AL 1–50	17	48	32	3	12	5.0	15.0	17	14
AS + L-S + CA $3\frac{1}{2}$–1–$\frac{3}{4}$–40	17	48	32	3	12	1.5	1.0	1	1
Series 9, 5–24–29									
Untreated	15	29	0	18	21	5.5	78.0	100	100
L-S 1–40	15	29	0	18	21	3.3	14.7	19	16
CaS 10–50	15	29	0	18	21	4.3	8.0	10	12
CaS 10–50 + AL 1–50	15	29	0	18	21	1.3	1.3	2	1
Bentonite-sulphur 5–50 + AL 1–50	15	29	0	18	21	2.7	11.0	14	10

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 10, 3–12–28									
Untreated	5	48	0	0	0	3.0	84.0	100	100
Kolotex	5	48	0	0	0	3.0	78.0	93	63
"	5	48	0	0	15	2.3	48.0	57	48
L-S 1–40 + AL 1–50	5	48	0	0	0	1.7	12.3	15	8
"	5	48	0	0	15	1.0	5.3	6	5
Untreated	5	72	0	0	0	4.0	71.3	100	100
Kolotex	5	72	0	0	0	2.5	80.5	113	113
"	5	72	0	0	15	1.0	30.5	43	20
L-S 1–40 + AL 1–50	5	72	0	0	0	2.5	46.5	65	33
"	5	72	0	0	15	1.7	5.0	7	4
Series 11, 4–7–28									
Untreated	10	45	0	0	0	4.2	35.6	100	100
Super sulfodust	10	45	0	0	0	4.4	36.0	101	124
"	10	45	0	0	20	3.3	37.7	106	77
Kolodust	10	45	0	0	0	4.7	50.3	141	137
"	10	45	0	0	20	5.0	55.6	156	168
Kolotex	10	45	0	0	0	5.0	46.0	129	181
"	10	45	0	0	20	3.0	27.4	77	65
L-S 1–40	10	45	0	0	0	1.3	5.0	14	10
"	10	45	0	0	20	0.0	0.0	0	0
L-S 1–40 + AL 1–50	10	45	0	0	0	0.0	0.0	0	0
"	10	45	0	0	20	0.3	0.3	1	0
AL 1–50	10	45	0	0	0	4.8	58.4	164	91
"	10	45	0	0	20	3.0	21.5	60	46
Series 12, 4–26–28									
Untreated	10	48	0	0	0	4.1	47.5	100	100
Kolodust	10	48	0	0	0	3.5	40.0	84	64

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 12, 4–26–28—Continued									
Kolodust	10	48	0	0	18	3.5	69.5	146	96
NaOH N/10	10	48	0	0	0	2.5	2.5	5	6
"	10	48	0	0	18	2.0	5.8	12	9
Series 13, 3–4–29 (Av. of 2 Ser.)									
Untreated	15	45	0	0	0	5.3	88.8	100	100
"	15	45	0	0	10	5.9	92.8	100	100
Kolodust	15	45	0	0	0	4.9	88.3	100	125
"	15	45	0	0	10	4.0	81.3	89	69
Ferrox sulphur paste 5–50	15	45	0	0	0	3.8	50.0	52	42
"	15	45	0	0	10	2.9	27.3	30	19
Thylox sulphur paste (unwashed) 5–50	15	45	0	0	0	0.8	1.3	2	0
"	15	45	0	0	10	0.0	0.0	0	0
Gray sulphur past 5–50	15	45	0	0	0	4.5	82.5	92	126
"	15	45	0	0	10	4.4	64.7	69	55
Series 14, 3–12–29									
Untreated	15	26	0	0	0	4.5	29.0	100	100
"	15	26	0	0	14	5.0	63.0	100	100
Kolodust	15	26	0	0	0	4.0	23.5	81	69
"	15	26	0	0	14	3.3	48.0	76	56
Ferrox sulphur paste 5–50	15	26	0	0	0	4.0	45.0	155	145
"	15	26	0	0	14	3.0	9.0	14	8
Gray sulphur paste 5–50	15	26	0	0	0	3.0	26.0	90	105
"	15	26	0	0	14	2.3	7.3	12	7
Series 15,[d] 6–17–29									
A Untreated (14 spores to low power)	20	12	0	61	18	5.3	41.0	100	100
B Untreated (1 spore to low power)	20	12	0	61	18	5.5	29.5	100	100

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 15,[d] 6–17–29—Continued									
A Untreated[e]	20	12	0	61	18	5.0	100.0	100	100
A Kolodust	20	12	0	61	18	3.3	30.7	75	49
B Kolodust	20	12	0	61	18	2.7	15.0	51	41
A Kolodust[e]	20	12	0	61	18	0.5	0.5	1	0
A Kolodust[f]	20	12	0	61	18	1.7	1.7	4	2
Series 16, 4–9–29									
Untreated	15	16	0	0	0	4.7	100.0	100	100
"	15	16	0	0	13	4.0	79.7	100	100
Kolodust	15	16	0	0	0	4.0	100.0	100	81
"	15	16	0	0	13	4.0	44.0	55	39
Aerated L-S 1–40	15	16	0	0	0	3.0	50.7	51	37
"	15	16	0	0	13	2.3	35.0	44	31
NaOH N/14	15	16	0	0	0	1.3	3.0	3	1
Soft soap 1%[e]	15	16	0	0	0	1.0	4.7	5	4
"	15	16	0	0	13	0.3	0.7	1	0
Stone lime 3–50	15	16	0	0	0	4.0	100.0	100	66
"	15	16	0	0	13	3.7	24.0	30	29
AL 2–50	15	16	0	0	0	4.0	100.0	100	107
"	16	15	0	0	13	4.7	100.0	125	129
Series 17, 6–12–29									
Untreated	20	35	0	0	0	6.5	100.0	100	100
"	20	35	0	0	12	7.0	100.0	100	100
Bentonite-sulphur 5–50	20	35	0	0	0	6.8	100.0	100	91
Bentonite-sulphur 5–50 + AL 1–50	20	35	0	0	0	6.0	100.0	100	67
"	20	35	0	0	12	4.7	52.0	52	20
CaS 10–50	30	35	0	0	0	5.3	100.0	100	61
CaS 10–50 + AL 1–50	20	35	0	0	0	8.0	100.0	100	126

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 17, 6–12–29—Continued									
CaS 10–50 + AL 1–50	20	35	0	0	12	2.8	32.0	32	12
L-S 1–40	20	35	0	0	0	5.0	79.3	79	44
117 1–50	20	35	0	0	0	5.3	100.0	100	77
"	20	35	0	0	12	6.8	100.0	100	89
117E 1–50	20	35	0	0	0	5.0	52.0	52	20
Series 18, 3–3–29									
Untreated	15	53	29	0	0	4.7	100.0	100	100
CaS 10–50	15	53	29	0	0	4.0	68.3	68	87
"	15	53	29	0	10	4.0	93.5	94	102
L-S 1–40	15	53	29	0	0	4.7	55.3	55	65
"	15	53	29	0	10	4.0	71.5	72	74
L-S 1–40 + AL 1–50	15	53	29	0	0	3.0	51.0	51	47
"	15	53	29	0	10	3.3	34.3	34	41
L-S 1–40 + CA 1–50	15	53	29	0	0	3.3	76.3	76	73
"	15	53	29	0	10	3.7	40.3	40	50
AS + L-S + CA $3\frac{1}{2}$–1–$\frac{3}{4}$–40	15	53	29	0	0	0.0	0.0	0	0
Series 19, 4–6–29									
Untreated	15	48	29	0	0	5.0	100.0	100	100
L-S 1–40	15	48	29	0	0	4.0	67.3	67	44
"	15	48	29	0	8	4.7	80.7	81	65
L-S 1–40 + AL 1–50	15	48	29	0	0	4.3	88.7	89	75
"	15	48	29	0	8	4.3	92.7	93	65
L-S 1–40 + CA 1–50	15	48	29	0	0	5.0	100.0	100	107
"	15	48	29	0	8	4.3	82.5	83	66
AS + L-S + CA $3\frac{1}{2}$–1–$\frac{3}{4}$–40	15	48	29	0	0	3.7	17.7	18	13
"	15	48	29	0	8	2.0	16.0	16	7

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 20, 3–30–29									
Untreated	15	45	30	4	0	7.5	64.0	100	100
L-S 1–40 + AL 1–50 (distilled water)	15	45	30	4	0	4.0	22.3	35	17
"	15	45	30	4	10	2.3	6.0	9	4
L-S 1–40 + AL 1–50 (lake water)	15	45	30	4	0	5.0	21.3	33	18
"	15	45	30	4	10	2.5	5.0	8	3
L-S 1–40 + CA 1–50 (distilled water)	15	45	30	4	0	3.8	23.7	37	20
"	15	45	30	4	10	3.2	4.0	6	4
L-S 1–40 + CA 1–50 (lake water)	15	45	30	4	0	5.3	38.7	60	36
"	15	45	30	4	10	2.5	6.5	10	4
Series 21, 4–5–29									
Untreated	15	48	12	0	0	6.7	100.0	100	100
L-S 1–40 + AL 1–50 (distilled water)	15	48	12	0	0	6.0	63.5	64	38
"	15	48	12	0	12	5.0	55.0	55	18
L-S 1–40 + AL 1–50 (lake water)	15	48	12	0	0	6.5	93.5	94	55
"	15	48	12	0	12	5.5	66.8	67	33
L-S 1–40 + CA 1–50 (distilled water)	15	48	12	0	0	6.2	92.2	92	43
"	15	48	12	0	12	5.5	74.7	75	33
L-S 1–40 + CA 1–50 (lake water)	15	48	12	0	0	6.0	100.0	100	64
"	15	48	12	0	12	5.0	59.5	60	27
Series 22,[d] 5–20–29									
A Untreated (48 spores to low power)	15	46	0	0	0	7.8	100.0	100	100
B Untreated (8 spores to low power)	15	46	0	0	0	7.0	100.0	100	100
A L-S 1–40 + AL 1–50	15	46	0	0	0	4.8	100.0	100	34
B L-S 1–40 + AL 1–50	15	46	0	0	0	4.5	59.0	59	29
A L-S 1–40 + AL 1–50	15	46	0	0	10	3.5	61.0	61	15
B L-S 1–40 + AL 1–50	15	46	0	0	10	3.0	20.0	20	6
A L-S 1–40 + AL 1–50[g]	15	46	0	0	10	3.7	33.7	34	12

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per tw'g			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 22,[d] 5–20–29—Continued									
B L-S 1–40 + AL 1–50[g]	15	46	0	0	10	1.5	2.0	2	1
A L-S 1–40 + AL 1–50	15	46	0	0	20	3.3	19.8	20	6
B L-S 1–40 + AL 1–50	15	46	0	0	20	1.8	13.5	14	3
Series 23,[d] 5–28–29									
A Untreated (14.6 spores to low power)	15	32	0	0	0	7.2	100.0	100	100
B Untreated (6.2 spores to low power)	15	32	0	0	0	7.4	89.8	100	100
A L-S 1–40	15	32	0	0	0	4.0	39.6	40	17
B L-S 1–40	15	32	0	0	0	3.4	24.1	27	13
Series 24, 3–21–29									
Untreated	15	48	24	0	12	4.7	36.7	100	100
L-S 1–25	15	48	24	0	12	2.0	9.7	26	15
L-S 1–40	15	48	24	0	12	2.7	7.0	19	13
L-S 1–80	15	48	24	0	12	3.0	17.7	48	33
L-S 1–120	15	48	24	0	12	3.5	19.8	54	38
L-S 1–25 + AL 1–50	15	48	24	0	12	0.7	4.0	11	5
L-S 1–40 + AL 1–50	15	48	24	0	12	2.3	8.3	23	17
L-S 1–80 + AL 1–50	15	48	24	0	12	2.7	3.3	9	8
L-S 1–120 + AL 1–50	15	48	24	0	12	2.0	13.3	36	29
Series 25, 6–9–28									
Untreated	16	34	14	0	8	4.0	40.5	100	100
L-S 1–120	16	34	14	0	8	1.3	7.3	18	16
L-S 1–80	16	34	14	0	8	2.0	5.5	14	20
L-S 1–40	16	34	14	0	8	2.2	2.2	5	4
L-S 1–40 4 hrs.	16	34	14	0	8	1.0	7.0	17	12
L-S 1–40 6.5 hrs.	16	34	14	0	8	0.5	4.0	10	7

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 25, 6–9–28—Continued									
L-S 1–40 8 hrs.	16	34	14	0	8	1.0	1.6	4	3
NaOH N/10	16	34	14	0	8	1.7	3.2	8	8
NaOH N/14	16	34	14	0	8	1.3	2.0	5	4
Series 26, 5–30–28									
Untreated	16	48	0	0	8	5.0	100.0	100	100
L-S 1–40 1 hr.	16	48	0	0	8	5.0	70.7	71	58
L-S 1–40 2 hrs.	16	48	0	0	8	3.3	100.0	100	53
L-S 1–40 4.5 hrs.	16	48	0	0	8	3.8	28.0	28	18
L-S 1–40	16	48	0	0	8	2.2	16.0	16	50
Series 27, 3–29–29									
Untreated	15	45	30	0	0	6.3	100.0	100	100
L-S 1–40 + AL 1–50	15	45	30	0	0	5.3	95.3	95	52
"	15	45	30	0	6	4.7	100.0	100	56
L-S 1–40 + AL 1–50 6 hrs.	15	45	30	0	6	5.0	97.7	98	55
L-S 1–40 + AL 1–50	15	45	30	0	12	4.0	52.7	53	27
L-S 1–40 + AL 1–50 12 hrs.	15	45	30	0	12	4.7	70.3	70	34
L-S 1–40 + AL 1–50	15	45	30	0	18	3.2	28.7	29	14
L-S 1–40 + AL 1–50 18 hrs.	15	45	30	0	18	5.0	68.5	69	33
Series 28, 4–17–28									
Untreated	10	66	0	24	5	4.7	37.0	100	100
L-S 1–40 + AL 1–50	10	66	0	0	0	2.0	4.3	12	8
L-S 1–40 + AL 1–50 (dried with fan)	10	66	0	0	0	1.8	1.6	4	3
L-S 1–40 + AL 1–50	10	66	0	0	4	2.6	5.4	15	10
L-S 1–40 + AL 1–50 + lime 3–50	10	66	0	24	5	1.5	4.5	12	9
L-S 1–25 + AL 1–50	10	66	0	24	5	0.5	1.5	4	3
AS + L-S + CA $3\frac{1}{2}$–1–$\frac{3}{4}$–40	10	66	0	24	5	0.7	1.2	3	2
NaOH N/10	10	66	0	24	5	1.8	4.2	12	7

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 29, 4–10–28									
Untreated	10	72	0	0	0	3.6	54.0	100	100
L-S 1–40 + AL 1–50	10	72	0	0	0	1.0	7.0	13	7
L-S 1–40 + AL 1–50 (dried with fan)	10	72	0	0	0	0.3	0.6	1	1
L-S 1–40 + AL 1–50 + Kayso ½–50	10	72	0	0	2	2.2	13.5	25	23
L-S 1–40 + Kayso ½–50 + AL 1–50	10	72	0	0	0	1.2	6.0	11	9
Kayso ½–50 + AL 1–50 + L-S 1–40	10	72	0	0	0	1.0	3.5	6	8
	10	72	0	0	0	1.0	4.0	7	4
Series 30, 4–24–28									
Untreated	10	48	24	2.5	10	5.5	82.2	100	100
L-S 1–40 + AL 1–50	10	48	24	2.5	10	2.6	10.6	13	10
L-S 1–40 + AL 1–50 + Kayso ½–50	10	48	24	2.5	10	1.5	5.5	7	4
L-S 1–40 + Kayso ½–50 + AL 1–50	10	48	24	2.5	10	2.5	8.5	10	12
Kayso ½–50 + AL 1–50 + L-S 1–40	10	48	24	2.5	10	3.3	22.0	27	21
L-S 1–40 + AL 1–50 + lime 3–50	10	48	24	2.5	10	3.0	26.5	32	16
Series 31, 5–26–28									
Untreated	15	48	42	0	10	5.5	98.8	100	100
L-S 1–40	15	48	42	0	10	4.3	64.3	65	31
L-S 1–40 + AL 1–50	15	48	42	0	10	3.7	70.0	71	28
L-S 1–40 + AL 1–50 + Kayso ½–50	15	48	42	0	10	4.3	100.0	101	50
L-S 1–40 + Kayso ½–50 + AL 1–50	15	48	42	0	10	3.2	31.2	32	11
Kayso ½–50 + AL 1–50 + L-S 1–40	15	48	42	0	10	3.5	73.5	74	37
L-S 1–40 + AL 1–50 + lime 3–50	15	48	42	0	10	4.3	49.6	50	20
Lime 3–50	15	48	42	0	10	4.3	92.0	93	58
Series 32, 4–1–29									
Untreated	15	45	27	5	8	6.0	46.8	100	100
L-S 1–40	15	45	27	5	8	4.0	16.3	35	28

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 32, 4–1–29—Continued									
L-S 1–40 + AL 1–50	15	45	27	5	8	2.3	11.0	24	12
L-S 1–40 + AL 1–50 (basic)	15	45	27	5	8	4.2	13.6	29	18
L-S 1–40 + As_2O_5 .002%	15	45	27	5	8	4.3	21.0	45	37
L-S 1–40 + As_2O_5 .01%	15	45	27	5	8	3.0	15.0	32	16
Series 33, 5–10–29									
Untreated	15	48	0	6	13	7.2	100.0	100	100
L-S 1–40	15	48	0	6	13	3.3	100.0	100	24
L-S 1–40 + AL 1–50	15	48	0	6	13	3.8	34.2	34	8
L-S 1–40 + As_2O_5 .02%	15	48	0	6	13	3.5	91.7	92	27
Series 34, 6–18–29									
Untreated	17	28	0	22	12	4.0	21.0	100	100
L-S 1–40	17	28	0	22	12	4.0	8.3	40	26
L-S 1–40 + AL 1–50	17	28	0	22	12	0.0	0.0	0	0
L-S 1–40 + As_2O_5 .02%	17	28	0	22	12	0.0	0.0	0	0
L-S 1–40 + As_2O_5 .04%	17	28	0	22	12	0.0	0.0	0	0
CaS 10–50	17	28	0	0	0	2.0	11.3	54	42
"	17	28	0	0	10	1.7	5.0	24	15
CaS 10–50 + AL 1–50	17	28	0	0	0	0.5	0.5	2	1
"	17	28	0	0	10	1.0	4.0	19	13
L20 2% + 117 1–50	17	28	0	0	0	2.3	9.0	43	33
L20 2% + 117E 1–50	17	28	0	0	0	2.2	5.2	25	19
Series 35, 6–22–29									
Untreated	21	35	0	69	0	4.0	78.5	100	100
L-S 1–40	21	35	0	69	8	2.5	25.5	32	22
"	21	35	0	45	24	0.0	0.0	0	0
L-S 1–40 + AL 1–50	21	35	0	69	8	0.0	0.0	0	0

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 35, 6–22–29—Continued									
L-S 1–40 + AL 1–50	21	35	0	45	24	1.0	2.3	3	2
L-S 1–40 + As_2O_5 .03%	21	35	0	69	8	0.5	1.0	1	1
" "	21	35	0	45	24	0.0	0.0	0	0
As_2O_5 .03%	21	35	0	69	8	4.0	26.0	33	28
" "	21	35	0	45	24	2.3	26.7	34	26
Series 36, 4–11–28									
Untreated	10	72	0	0	0	3.8	69.8	100	100
Kolotex	10	72	0	0	0	2.5	26.5	38	30
Kolotex 8–50 + soft soap 1%[c]	10	72	0	0	0	0.7	16.5	24	14
Kolotex 8–50 + Kayso ½–50	10	72	0	0	0	2.8	21.2	30	26
Kolotex 8–50 + lime 3–50	10	72	0	0	0	1.8	5.4	8	6
Kolotex 8–50 + L202 2%	10	72	0	0	0	2.0	12.3	18	9
L-S 1–40 + AL 1–50	10	72	0	0	0	1.4	7.6	11	8
Series 37, 4–29–28									
Untreated	10	48	0	0.5	8	3.7	50.2	100	100
Oxidized sulphur 8–50	10	48	0	0.5	8	4.2	88.0	175	197
Kolodust 8–50	10	48	0	0.5	8	3.6	19.3	38	37
Kolotex 8–50 + soft soap 1%[c]	10	48	0	0.5	8	0.6	1.0	2	2
Kolodust 8–50 + L202 2%	10	48	0	0.5	8	1.0	4.0	8	5
Ferrox sulphur paste 8–50	10	48	0	0.5	8	3.0	24.2	48	56
Series 38, 4–23–29									
Untreated	15	30	0	18	8	7.8	100.0	100	100
L-S 1–40	15	30	0	18	8	3.8	15.8	16	8
L20 2%	15	30	0	18	8	6.7	88.7	89	49
L205 2%	15	30	0	18	8	4.5	20.0	20	9
L20 2% + K-I-CB 2–50	15	30	0	18	8	2.7	8.0	8	3

TABLE 2—(*Continued*)

Series, date, and fungicide[a]	Inoculation chamber		Period in Grh[b] before fung. applied	Subsequent treatment		Final results averaged per twig			
	Temp.	Period in		In Grh	In IC[b]	Leaves infected	Max. lesions on one leaf		Total lesions
	°C.	Hrs.	Hrs.	Hrs.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 38, 4–23–29—Continued									
L20 2% + Bentonite-sulphur 5–50	15	30	0	18	8	5.5	29.8	30	22
Bentonite sulphur 5–50	15	30	0	18	8	6.5	57.0	57	41
Bentonite-sulphur 5–50 + soft soap 1%[b]	15	30	0	18	8	3.2	13.0	13	7
Soft soap 1%[b]	15	30	0	18	8	5.5	57.2	57	37
Series 39, 5–22–29									
Untreated	15	30	0	10	10	6.8	100.0	100	100
L20 2%	15	30	0	10	10	9.0	100.0	100	125
L205 2%	15	30	0	10	10	6.0	100.0	100	89
L20 2% + 117 1–50	15	30	0	10	10	1.7	7.0	7	2
L20 2% + 117c 1–50	15	30	0	10	10	2.0	23.0	23	6
L20 2% + 118 1–50	15	30	0	10	10	3.3	35.3	35	12
L20 2% + K-1-CB 1–50	15	30	0	10	10	4.2	34.8	35	17
Series 40, 5–29–29									
Untreated	15	24	0	0	0	5.5	100.0	100	100
L20 2%	15	24	0	0	0	8.0	100.0	100	87
L205 2%	15	24	0	0	0	5.0	47.5	48	30
L20 2% + 117 1–50	15	24	0	0	0	4.0	16.0	16	10
L20 2% + 117c 1–50	15	24	0	0	0	1.7	11.7	12	5
L20 2% + 118 1–50	15	24	0	0	0	4.7	16.0	16	10
L20 2% + K-1-CB 1–50	15	24	0	0	0	3.7	14.8	15	7

[a] Explanation of abbreviations used in the table follows (for more details see p. 446):

Sulphur dusts

Oxidized sulphur = Sublimed sulphur plus potassium permanganate and a catalyst.
Precipitated sulphur = Derived from aerated lime sulphur.
Bentonite-sulphur = Sulphur fused with bentonite.

Explanation of abbreviations (*Continued*)

Sulphur spray

L-S = Commercial liquid lime sulphur.

Arsenicals

AL = Commercial powdered arsenate of lead.

CA = Commercial powdered arsenate of lime.

Copper fungicides

BM = Bordeaux mixture.

C-L-Ars. = Copper-lime-lead arsenate.

Emulsified oil sprays

L20, L202 } Emulsified oils.

L205 = L20 plus a form of sulphur.

Mercurial compounds

K-l-CB, K-l-GB } Proprietary organic ethyl mercury chloride compounds.

117, 117[c], 117[e] } Proprietary organic hexamethylene bichloride of mercury compounds.

118 = A pure monobasic mercurial compound.

Other materials

AS = Aluminum sulphate.

Kayso = Casein lime.

[b] Grh = Greenhouse. IC = Inoculation chamber.

[c] Neutral sodium soft soap (20th Century Soap).

[d] Abundance of the ascosporic inoculum was observed by microscopic examination of Petri plates exposed in representative situations in the chamber. The data refer to the approximate number of spores per low-power field of the microscope. The capital letters A and B differentiate the trees with respect to the amount of inoculum they received as indicated in the controls.

[e] Trees were given 12 hours in inoculation chamber immediately after treatment.

[f] The dusted trees were sprinkled with distilled water and then given moist treatment as in [e].

[g] The treated trees were sprinkled with distilled water 2 and 4 hours, respectively, after putting in inoculation chamber.

[h] Neutral potassium soft soap (XXX Cork Tile Soap).

periods of 48 and 81 hours at 6° C. in the moist chamber. Lime-sulphur preparations were the most effective in this inhibition. According to Greaney (26), who worked with certain cereal rusts, the length of time after inoculation during which control can be obtained with Kolodust is short and varies with the temperature, the period being from 10 hours at 10° to 12° C. to 5 hours at 22° to 24° C.

The present writer obtained excellent control of apple scab when treatments, particularly the sprays containing lime sulphur, followed soon after infection periods. Considerable differences were found in the effectiveness of the various fungicides when applied after inoculation. Sprays containing lime-sulphur were distinctly more effective than treatments of sulphur dusts (whether finely ground, sublimed, activated or containing arsenate of lead), wettable sulphur sprays, calcium monosulphide, Bordeaux mixture, emulsified oils with or without a sulphur fungicide, and certain proprietary mercurial compounds (Table 1, Ser. 6–15, and Table 2, Ser. 1–4, 7, 10, 11, 17, 18, 34, 36, 38). The greater toxicity exhibited by the sprays containing lime sulphur as compared with these other fungicides was dependent apparently neither on temperature within the range of 5° to 23° C. nor on the presence of high humidity after application. It appears that sulphur-arsenate dust, 90–10, offered little control when applied later than 12 hours following inoculations unless the application was followed by a moist treatment (Table 1, Ser. 6–15). Sprays containing lime sulphur, especially lime sulphur 1–40 plus arsenate of lead 1–50, gave good control when the application was made after infection periods ranging from 30 to 72 hours, and in some cases even longer (Table 1, Ser. 6–15; Table 2, Ser. 1–4, 7–11, 17–36; and Table 3, Ser. 3, 4). Lime sulphur-aluminum sulphate mixture was the most effective spray tested (Table 2, Ser. 8, 18, 19, 28). Lime sulphur 1–40 was not quite so effective as lime sulphur 1–40 plus arsenate of lead 1–50 (Table 2, Ser. 2, 7, 8, 11, 18, 19, 24, 31–35). This difference was decidedly more marked when a period in the moist chamber followed the application of the sprays. The results (Table 2, Ser. 24, 25) seem to be in general accord with field evidence that 1–40 is a satisfactory dilution for the lime-sulphur concentrate in apple-scab control. Under these conditions, there seemed to be no significant difference in fungicidal effectiveness attributable to their various physical states between the several wettable sulphur pastes or finely ground sulphur preparations and the less finely divided sulphur products (Table 1, Ser. 14, 15, and Table 2, Ser. 1, 2, 4, 5, 11, 13, 14, 16, 37). The amount of control obtained with precipitated lime sulphur appeared to be equal to that obtained with certain sulphur dusts and wettable sulphur pastes (Table 1, Ser. 14, 15, and Table 2, Ser. 5, 16). There is evidence that the wettable particulate sulphur pastes, which are by-products in the purification of

natural gas, contained a component other than sulphur, the toxic effect of which is increased in the presence of moisture. Calcium monosulphide, applied after infection periods of from 28 to 53 hours at 15° to 20° C., did not seem quite so toxic as lime sulphur 1–40 (Table 2, Ser. 9, 17, 18, 34). (Hurt and Schneiderhan (28).)

Bordeaux mixture, applied after infection periods of from 46 to 72 hours at 10° to 23° C., gave more consistent and better control than certain sulphur dusts and finely divided sulphur sprays (Table 2, Ser. 1–3). Emulsified oils, L202 and L20, appear to have fungicidal properties, although these may vary with the breaking point of the emulsion and with other factors (Table 2, Ser. 1, 3, 4, 38–40). L205, an emulsified oil containing a form of sulphur, did not appear to offer so good control as the sprays containing lime sulphur, although it seemed more toxic than oil emulsion alone, certain sulphur dusts and wettable sulphur sprays, and Bordeaux mixture (Table 2, Ser. 1–4, 38). Proprietary mercurial compounds, K–1–CB, K–1–GB, and 117E may be quite effective when applied 35 to 94 hours after inoculation (Table 2, Ser. 7, 17). K–1–CB is more effective than K–1–GB (Table 2, Ser. 7). In K–1–CB the toxic material is more soluble and volatile than in K–1–GB. K–1–CB, 117, 117C, 117E, and 118 (Table 2, Ser. 34, 38–40) decidedly increase the effectiveness of oil emulsion, L20, under these conditions and appear to warrant further investigations as fungicides for oil emulsions.

Kolodust, lime sulphur 1–40 plus arsenate of lead 1–50, and lime sulphur 1–40, applied 12, 46, and 32 hours, respectively, after inoculation began, show that the quantity of ascosporic inoculum was an important factor in the effectiveness of the sulphur fungicides (Table 2, Ser. 15, 22, 23). Further data of the same general trend appear in the other series in table 2.

The question arises as to the feasibility of applying fungicides after infection periods in the field. Since no orchard spraying experiments were included in the present investigation this point can not be discussed in detail. However, it may be recorded that unpublished results made available to the writer by Keitt and Wilson are in conformity with those obtained in the greenhouse and show striking effectiveness of lime sulphur plus lead arsenate in controlling apple scab when applied soon after an infection period. From the evidence at hand it would appear that prompt spraying with lime sulphur and lead arsenate after critical infection periods should be of much value in emergency situations in which the trees have not been adequately protected during such periods.

RELATION OF TEMPERATURE TO THE EFFECTIVENESS OF SULPHUR FUNGICIDES

Considerable theoretical and practical interest attaches to the relation of temperature to the fungicidal action of sulphur preparations. Marès

(33) wrote that sulphur will destroy the powdery mildew of the grape wherever the sulphur touches it, provided the temperature is not below 20° C. Doran (10) concluded that the toxicity of the sulphur to fungi increases with rise of temperature and length of time of exposure. He reported that sulphur dust was toxic to the conidia of *Venturia inaequalis* when the temperature remained at 26° C. for five hours. Butler (7) considered that temperature was an important factor in the effectiveness of sulphur in the control of snapdragon rust. He reported that sulphur was quite ineffective at temperatures below 15° C. Tisdale (52) stated that the toxicity of colloidal sulphur (prepared from sulphur dioxide and hydrogen sulphide) to *Botrytis cinerea* Pers. was greater at the higher temperatures tested. According to Butler and Doran (8), the toxicity of lime-sulphur solution depends on the temperature preceding spore germination. Goodwin and Martin (24) found that the amount of a volatile sulphur derivative formed from sulphur increased with a rise in temperature when tested by a copper-foil method. However, these tests were feasible only at comparatively high temperatures. In a later paper Goodwin and Martin (25) offered evidence to indicate that the production of gaseous sulphur at ordinary temperatures was insufficient to be effective against the conidia of *Sphaerotheca humuli* (DC.) Burr and *Erysiphe graminis* DC., although sulphur is known to be toxic to these two fungi. They found, however, that the gall mite, *Eriophyses ribis*, was affected by the traces of sulphur volatilized at ordinary temperatures. It is evident from the data of Keitt and Jones (29) that various sulphur treatments including sulphur dust alone were effective against *V. inaequalis* at 6° C. Greaney (26) found that a temperature as low as 12° C. had very little influence upon the effectiveness of sulphur dust when applied before infection in the control of some cereal rusts but reported that the length of time during which control could be obtained when applications were made after inoculation varied with the temperature. At temperatures of 10° to 12° C. sulphur prevented any serious infection when applied 10 hours after inoculation, while at the higher temperatures, 22° to 24° C., it was equally effective when applied 5 hours after inoculation. The increased period of effectiveness at the lower temperatures was accounted for by the slower development of the rust fungus in that environment rather than by an increase in activity of the sulphur. As the result of an investigation of the control of brown rot of peaches in storage with Koppers sulphur dust, Smith (48) reported that definite fungicidal action was exerted by sulphur at 40° F. However, he obtained no control of brown rot at temperatures of 65° F. and above. The relation of temperature to the growth of the pathogene should be considered in interpreting these results.

TABLE 3.—*Relations of temperature and humidity to the effectiveness of Kolodust and sprays containing lime sulphur when applied after inoculation of Wealthy apple leaves with the ascospores of Venturia inaequalis*

Series, date, and fungicide[a]	Period in IC[a] at 15° C.	Period in Grh[a] before fung. app.	Subsequent treatment of plant[a]	Final results averaged per twig			
				Leaves infected	Max. lesions on one leaf		Total lesions
	Hrs.	Hrs.		No.	No.	Rel. No.	Rel. No.
Series 1,[b] 3–20–29							
Untreated	24	0	24 hrs. 18°–55% Grh[a]	5.3	83.0	100	100
Kolodust	24	0	"	4.7	77.7	94	62
Untreated	24	0	24 hrs. 28°–50% Grh	5.0	65.7	100	100
Kolodust	24	0	"	5.0	37.3	57	57
"	24	0	" [c]	3.3	23.3	35	32
Untreated	24	0	24 hrs. 28°–80% Grh	4.0	76.5	100	100
Kolodust	24	0	"	2.7	17.0	22	22
"	24	0	" [c]	3.0	11.0	14	15
Untreated	24	0	Intermittent 28°–80% Grh[d]	5.0	28.0	100	100
Kolodust	24	0	"	3.3	12.3	44	38
Series 2,[c e] 3–22–29							
Untreated	4	0	18°–55% Grh[a]	5.2	85.0	100	100
Kolodust	4	0	6 hrs. 18°–55% Grh	3.8	37.3	44	39
"	4	0	9 hrs. 18°–55% Grh	2.2	10.2	12	12
"	4	0	18 hrs. 18°–55% Grh	2.3	2.5	3	2
Untreated	4	0	9 hrs. 28°–80% Grh	5.0	36.2	100	100
Kolodust	4	0	3 hrs. 28°–80% Grh	3.2	9.4	26	28
"	4	0	6 hrs. 28°–80% Grh	3.0	6.3	17	9
"	4	0	9 hrs. 28°–80% Grh	1.0	1.1	3	2
Series 3, 4–13–29							
Untreated	48	24	18°–55% Grh[a]	7.0	62.0	100	100
L-S 1–40	48	24	"	5.3	92.3	149	87
L-S 1–40 + AL 1–50	48	24	"	5.6	54.0	87	43
Untreated	48	24	24 hrs. 26°–47% Grh	7.0	62.5	100	100
L-S 1–40	48	24	"	3.8	15.0	24	14
L-S 1–40 + AL 1–50	48	24	"	4.0	19.5	31	15
"	48	24	48 hrs. 26°–47% Grh	2.7	15.0	24	9

TABLE 3—(*Continued*)

Series, date, and fungicide[a]	Period in IC[a] at 15° C.	Period in Grh[a] before fung. app.	Subsequent treatment of plant[a]	Final results averaged per twig			
				Leaves infected	Max. lesions on one leaf		Total lesions
	Hrs.	Hrs.		No.	No.	Rel. No.	Rel. No.
Series 3, 4–13–29—Continued							
Untreated	48	24	48 hrs. 26°–83% Grh	7.0	59.0	100	100
L-S 1–40 + AL 1–50	48	24	"	2.5	7.0	12	7
Series 4, 4–16–26							
Untreated	45	27	18 hrs. IC, 18°–55% Grh[a]	7.2	100.0	100	100
L-S 1–40 + AL 1–50	45	27	"	3.3	34.8	35	12
Untreated	45	27	26 hrs. 30°–80% Grh	4.0	27.5	100	100
L-S 1–40 + AL 1–50	45	27	6.5 hrs. 30°–80% Grh	2.5	38.8	141	58
"	45	27	18 hrs. 30°–80% Grh	1.3	2.5	9	7
"	45	27	26 hrs. 30°–80% Grh	0.0	0.0	0	0

[a] Temperature in °C. Relative humidities in per cent. Grh = Greenhouse. IC = Inoculation chamber. L-S = Commercial liquid lime sulphur. AL = Commercial powdered arsenate of lead. The plants were incubated, except as otherwise stated, in a greenhouse which was approximately 18° to 23° C. and 50 to 60% relative humidity, without effort to control humidity.

[b] Series was given 24 hours in the inoculation chamber following the treatment above.

[c] Thoroughly washed with a spray of lake water following the temperature treatment.

[d] Six periods of 12 hours each were alternated between 28°–80% and 20°–50% greenhouses, respectively.

[e] Series was in the inoculation chamber for 48 hours at 15° C. 18 hours after inoculation.

Good control was obtained with sulphur dusts and sprays applied before inoculation when temperatures of from 5° to 24° C. were maintained during the infection period (Table 1, Ser. 1–5, 8, 9, 11–18; Table 6, Ser. 1–7; and Table 7, Ser. 1–3). Kolotex gave complete control at 2.5° C. (Table 1, Ser. 16); but, as is shown later, this may have been due in part to the arsenate of lead. Fungicidal applications made after infection show that temperatures within the range of from 6° to 23° C. during an infection period did not materially affect the control of *Venturia inaequalis* (Tables 1 and 2). Temperatures of 26° C. and above, during the period following the discharge of ascospores, may be an important factor in the amount of control (Table 3, Ser. 1–4). It appears that the amount of infection obtained in the controls was determined by the temperature and length of exposure to the temperature, if this was near the upper limit of toleration for the fungus. It is apparent that high temperatures were more effective in preventing infection than in checking the organism after it had become well established in the host. Temperatures above 26° C. markedly inhibited infection by *V. inaequalis*. Brief exposures to a temperature of 28° C. distinctly increased the effectiveness of Kolodust applied 24 hours after inoculation (Table 3, Ser. 1). Kolodust, applied after an infection period of 4 hours at 15° C., effected as much control in 9 hours at 28° C. as in 18 hours at 18° C. (Table 3, Ser. 2). It will be noted that the beneficial result of a rise in temperature on the effectiveness of sulphur dust was more marked when the treatment was made soon after inoculation. The control obtained with lime sulphur 1–40 and lime sulphur 1–40 plus arsenate of lead 1–50, applied 72 hours after inoculation, was decidedly greater at 26° to 30° C. than at 18° C. (Table 3, Ser. 3, 4). The effectiveness of the spray increased markedly according to the length of the exposure to the higher temperatures. It is evident from these experiments that consideration must be given to the effect of temperature, not only on the action of the sulphur fungicide but also on the growth of the fungus and of the host and on the host-parasite relation.

The minimal number of hours of continuous wetting necessary for infection by ascospores of *Venturia inaequalis* was reported by Keitt (30) as follows: 6°, 15; 9°, 11; 15°, 7; 20°, 4; and 24° C., 6.

THE RELATION OF MOISTURE TO THE EFFECTIVENESS OF CERTAIN FUNGICIDES

Doran (9) reported that sulphur was nontoxic to the urediniospores of *Puccinia antirrhini* Diet. & Holw. when applied in water but was toxic when applied dry. Barker, Gimingham, and Wiltshire (2) observed that spores of *Sclerotinia fructigena* Pers., on the outside of the film of a hanging drop, did not germinate when dry precipitated sulphur was added to

the outside of the drop, but spores that were wet and remained suspended in the center of the drop germinated well. Yossifovitch (64) considered that the action of sulphur in the control of Oidium of the vine was diminished by humidity. Young (61), using the spores of *S. cinerea* with a hanging-drop technique, concluded that a certain water requirement was necessary for sulphur to be effective. Greaney (26), in a study of the control of some cereal rusts, found that the effectiveness of sulphur was greatly reduced when free moisture was abundant either before or after inoculation. The relation of moisture to the passage of a volatile substance across space was investigated by Goodwin and Martin (24), who made a quantitative estimate of the stain produced by the reaction of a volatile material from sulphur with copper. They found that the influence of humidity on the production of the stain was negligible, although there was evidence that its formation was favored in the absence of moisture.

A period of 12 hours in the moist chamber, ending 6 hours before inoculation, did not have a noticeable inhibitory effect on the fungicidal action of sulphur dusts and sprays applied 24 hours before inoculation (Table 1, Ser. 1–3, 8, 9, 11–14). Aerated lime sulphur 1–40, Koloform, Kolodust, and Super-sulfodust, applied 30 to 48 hours after inoculation, did not prevent further infection when the treated plants were placed in the moist chamber for 15 to 20 hours at 10° to 14° C. (Table 1, Ser. 14, and Table 2, Ser. 11, 12). However, applications of Kolodust, made following periods in the moist chamber of from 12 to 45 hours at 15° to 20° C., indicate that a moist treatment increased the amount of control (Table 2, Ser. 13–16), although there might be at the same time actually an increase in the amount of infection in treated trees. It should be noted that the controls (Table 1, Ser. 14, Table 2, Ser. 11, 12) were in the moist chamber only during the infection period. Had they received the second moist treatment along with the treated trees, it is probable that more disease would have developed. This fact may account for what appears to have been a decrease in toxicity incident to subjecting the treated plants to the moist period. It is evident that the sulphur was not sufficiently toxic under these conditions to prevent further development of the fungus. The degree to which moisture effected an increase in the toxicity of the sulphur was apparently greater when the application was made a comparatively short time after inoculation. A surplus of water applied to the sulphur after the application did not tend materially to affect its toxicity (Table 2, Ser. 15). Moist treatments, ranging from 15 hours at 5° C. to 20 hours at 10° C., following fungicidal applications, markedly increased the effectiveness of sulphur-arsenate dust 90–10 (Table 1, Ser. 12–14); Kolotex (Table 2, Ser. 10, 11); arsenate of lead (Table 2, Ser. 11, 16); Bentonite-sulphur 5–50 plus arsenate of lead

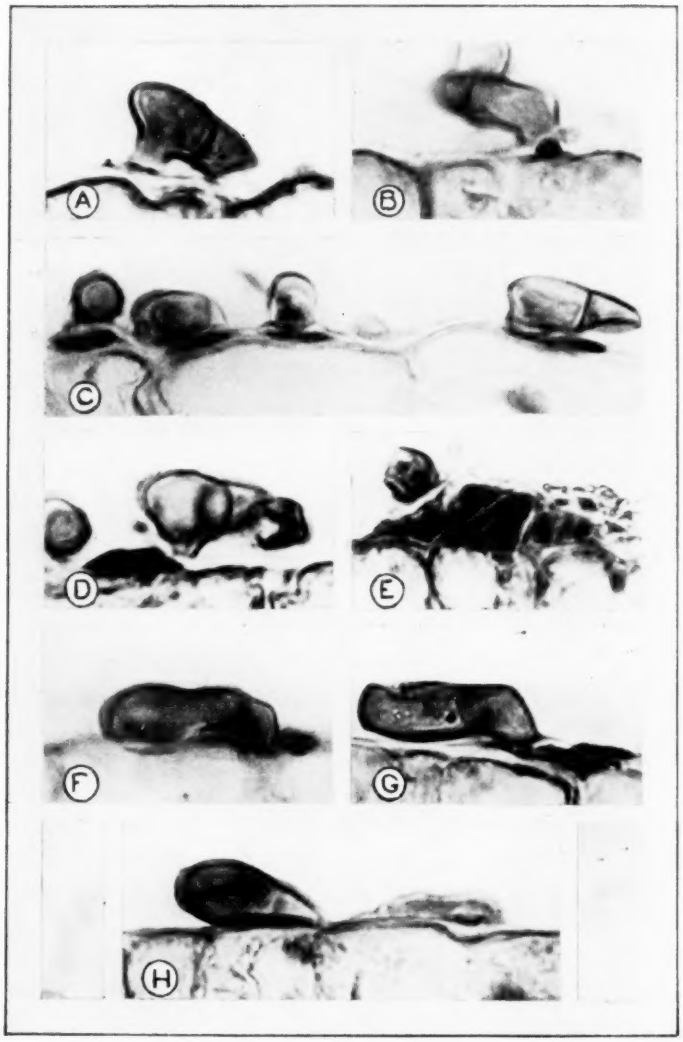

FIG. 3. Penetration of *Venturia inaequalis* into the ventral surface of Wealthy apple leaves in relation to the action of certain fungicides. All figures × 1016. A. Germinated ascospore after 7 hours in moist chamber at 20° C. No penetration. B. Infection established after 10-hours incubation at 17° C. C. Penetration after 24-hours incubation at 17° C. D. Typical infection of leaf treated with Kolodust after 10-hours incubation at 17° C., followed by 14-hours moist treatment at 17° C. before fixation. E. Subcuticular development of fungus after 50-hours incubation at 20° C. Plants then sprayed with lime sulphur 1–40 plus arsenate of lead 1–50 and given 18-hours moist treatment at 20° C. F, G. Penetration from conidia after 24 and 30 hours, respectively, incubated at 15° C. H. An appressorium formed by a conidium after 24-hours incubation at 15° C.

1–50 (Table 2, Ser. 17); calcium monosuphide 10–50 plus arsenate of lead 1–50 (Table 2, Ser. 17, 34); calcium monosulphide 10–50 (Table 2, Ser. 18,[5] 34); Ferrox sulphur paste 5–50, Thylox sulphur paste (unwashed) 5–50, and Gray sulphur paste 5–50 (Table 2, Ser. 13, 14); and stone lime 3–50 (Table 2, Ser. 16). The fungicidal actions of lime sulphur 1–40 plus arsenate of lead 1–50 (Table 1, Ser. 12–14, and Table 2, Ser. 10, 11, 18–22, 27, 35); lime sulphur 1–40 plus calcium arsenate 1–50 (Table 2, Ser. 18–21); and lime sulphur 1–40 (Table 1, Ser. 14, and Table 2, Ser. 11, 18,[5] 19,[5] 35) were also decidedly increased by similar treatments. The increased inhibiting effect of lime sulphur 1–40 plus arsenate of lead 1–50, due to a moist treatment following its application, was dependent upon the duration of the treatment (Table 2, Ser. 22, 27). An increase in humidity below the saturation point at 26° C. or above appears to aid the sulphur dusts and sprays containing lime sulphur in checking the fungus (Table 3). Other indications of the relation of moisture to the efficiency of the various sprays may be found by further study of table 2.

HISTOLOGICAL STUDIES ON PENETRATION OF THE FUNGUS IN RELATION TO THE ACTION OF CERTAIN FUNGICIDES

Studies were made of infection of leaves of potted Wealthy apple plants at various intervals after inoculation with conidia and ascospores of *Venturia inaequalis*. The conidia were washed from abundantly sporulating lesions on freshly collected apple leaves and sprayed upon the experimental apple leaves by means of an atomizer. The ascospores were ejected from perithecia in overwintered apple leaves directly upon susceptible leaves that previously had been wetted. Inoculations were made on the upper side only. Plants with leaves of approximately the same age and texture were used. Infection was accomplished in the moist chamber. Portions of inoculated leaves at the desired stages of infection or after certain fungicidal treatments were placed in formal-acetic alcohol, and parowax serial sections were prepared from them. Safranin and fast green proved to be the most successful combination of stains tried. The safranin stained the fungal hyphae within the host red, and the fast green stained the cuticle and epidermal layer of cells of the leaf green, thus giving a striking contrast.

Studies of the fixations of the conidial material supported, in general, the results of Keitt and Jones (29) and those of certain workers quoted by them. The well-differentiated appressorium (Fig. 3, H), considered a typical development before infection, was somewhat uncommon under these conditions as compared with the relatively short, thick germ tubes (Fig. 3,

[5] These data are inconsistent with the general trend. The period which elapsed before the moist treatment was given appears to have been a factor.

F, G) that appeared to function as appressoria without the formation of clearly differentiated holdfasts. Sections F, G, and H (Fig. 3), referred to above, were prepared from fixations made after infection periods of 24, 30, and 24 hours, respectively, at 15° C. When ascospores were used as inoculum, infection was not preceded in the majority of cases by the development of a well-differentiated appressorium. This was especially true if the spores became situated on susceptible leaf surface. Modifications of the germ tube have been noticed in cases where for some reason the germ tube did not originate or develop near the leaf surface but came in contact with it some distance from the spore. The ascospore itself (Fig. 3, A, B, C, D) may function as an appressorium from which an infection hypha may penetrate directly into the cuticle, as reported by Keitt and Jones (29). However, it is not uncommon to find comparatively short, thick germ tubes (Fig. 3, A, B, D) which probably function as holdfasts. As pointed out by Keitt and Jones (29), this type of infection is important in relation to the effectiveness of fungicides, as it shortens the time necessary for infection and reduces the area exposed to the action of a toxic agent before infection occurs. Sections (Fig. 3, A, B, C), made after infection periods of 7, 10, and 24 hours, respectively, at 17° C., show the different stages of infection under these conditions. Penetration was not observed for an infection period of less than 10 hours. It is evident from a comparison of B and D (Fig. 3) that Kolodust, applied after an infection period of 10 hours, was ineffective when the application was followed by a period in the moist chamber of 14 hours at 17° C. The stage of infection shown in figure 3, D, is as far advanced as that of figure 3, C, in which no sulphur dust was applied. Figure 3, E, shows a stage of infection following a period of 50 hours at 20° C. in the moist chamber after inoculation began. Lime sulphur 1–40 plus arsenate of lead 1–50, applied at this time and followed by a moist treatment of 18 hours, gave good control.

DISCUSSION

It would seem from the data that have been presented that sulphur dusts gave an initial control as great as that of the sprays when applied before inoculation and left in place. It is apparent, as found by Keitt and Jones (29), that the various sulphur treatments with or without arsenate of lead are effective at a temperature as low as 6° C. This accords with their field data and with the results of others who have obtained satisfactory control of apple scab at comparatively low temperatures in the spring. It is against the view of those investigators who have maintained that finely divided sulphur is not effective at these low temperatures. It is evident that the subjection of a sulphured plant to a period in the

moist chamber before inoculation has no inhibitory effect on the fungicidal action of sulphur provided there is no washing action, and that, if moisture or water is an essential for sulphur to be effective, there was a sufficient quantity available during the infection periods.

The data show that it is possible to control *Venturia inaequalis* soon after infection by applying certain fungicides, notably sprays containing lime sulphur. Other sprays and dusts tested are markedly less effective. Sprays containing lime sulphur have repeatedly given control when applied after intervals ranging from 30 to 72 hours or even longer after inoculation, while sulphur-arsenate dust has not been so effective after 12 hours. Histological evidence would indicate that sulphur dust had no appreciable effect on *V. inaequalis* after infection was established, while lime sulphur plus arsenate of lead was effective after considerable subcuticular development of the fungus. Temperature is apparently an important factor in the inhibition of the fungus (through its relationship to host and parasite) and in the amount of control effected by the sulphur fungicide. Moisture, in part, determines the maximum control obtainable with the use of many fungicides, particularly those containing an arsenical compound. From the evidence at hand it would appear that prompt spraying with lime sulphur and lead arsenate after critical infection periods should be of much value in emergency situations in which the trees are not adequately protected during such periods.

OTHER STUDIES CONCERNING THE EFFECTIVENESS OF CERTAIN FUNGICIDES

During the course of these studies it has not been feasible to make more than an exploratory investigation of some factors which bear upon the control obtained with certain fungicides A brief record of the results of this phase of the investigation follows.

Time required for sprays containing lime sulphur and Kolodust to be effective when applied after inoculation. The nature of fungicidal effectiveness and the time required for toxicity to be exhibited are of material significance in the evaluation of a spray or dust. The toxicity of a fungicide is generally expressed as a killing or an inhibitory action. A consideration of the latter phase of toxicity involves the question as to whether the fungus is continuously held in check by the fungicide or only inhibited long enough for the host to outgrow it or become resistant to its invasion. The time required for sulphur to be effective when applied after an infection period of 4 hours was determined, at least in part, by the temperature that followed the application (Table 3, Ser. 2). While Kolodust may require 18 hours to be effective at a temperature of 18° C., it may exhibit the same degree of toxicity in 9 hours at 28° C. The amount of infection on the control for the 28° C. treatment was markedly reduced as compared to that of the control held at 18° C.

TABLE 4.—*The rate of fungicidal action of Kolodust and lime sulphur 1–40 applied after inoculation of Wealthy apple leaves with the ascospores of Venturia inaequalis*

Series, date and fungicide[a]	Period in IC[a] at 16° C.	Period in Grh[a]	Period for fung. action[b]	Incubated in IC at 16° C.	Final results averaged per twig			
					Leaves infected	Max. lesions on one leaf		Total lesions
	Hrs.	Hrs.	Min.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 1, 6–4–28								
Untreated	2	1	0	44	0.7	1.0	.....	.....
Kolodust	2	1	10	44	0.3	2.0	.....	.....
"	2	1	60	44	0.3	0.3	.....	.....
Untreated	9	0	0	44	2.5	2.5	.....	.....
Kolodust	9	0	10	44	1.8	3.5	.....	.....
"	9	0	60	44	1.0	1.5	.....	.....
Series 2, 6–12–28								
Untreated	0	0	0	30	6.2	63.0	100	100
"	2	1	0	30	2.0	8.0	13	5
"	3	0	0	30	3.5	34.5	55	35
L-S 1–40	2	0	10	30	0.0	0.0	0	0
"	2	0	60	30	0.0	0.0	0	0
Untreated	9	0	0	30	6.0	73.0	100	100
L S 1–40	9	0	10	30	0.0	0.0	0	0
"	9	0	60	30	0.7	4.0	6	3
Series 3, 3–7–29								
Untreated	0	0	0	48	6.3	100.0	100	100
"	2	0	0	48	3.2	20.5	21	12
"	2	1	0	48	4.3	49.5	50	18
"	4	0	0	48	4.0	55.0	55	32
"	4	1	0	48	6.5	100.0	100	109
"	6	0	0	48	5.3	100.0	100	95

[a] L-S = Commercial liquid lime sulphur. Grh = Greenhouse. IC = inoculation chamber.
[b] After stated intervals the leaves were thoroughly washed with a spray of lake water.

Lime sulphur 1–40 gave control if it remained on the foliage for a period of 10 minutes at 16° C., when applied following periods of 3 and 9 hours, respectively, after inoculation (Table 4, Ser. 2). Although the trees were given a thorough washing with a spray of water, it is possible that the foliage or the spores still retained some of the lime sulphur. The trees were kept in the moist chamber from the time of inoculation to that of washing, thereby preventing the drying of the lime sulphur. Considerable infection occurred when lime sulphur 1–40, applied at the end of an infection period of 48 hours at 16° C., was washed off after 4½ hours in the moist chamber (Table 2, Ser. 25, 26). It required about 8 hours in the moist chamber for maximum effectiveness to be exhibited under these conditions. Lime sulphur 1–40 plus arsenate of lead 1–50, applied after an infection period of 75 hours, did not fully inhibit the fungus after a moist treatment of 18 hours (Table 2, Ser. 27). Lime sulphur 1–40 plus arsenate of lead 1–50, applied 72 hours after inoculation, gave very poor control when the trees were incubated at 18° C. immediately following treatment (Table 3, Ser. 4). Excellent control was obtained, however, when the treated trees were incubated at 30° C. for 18 hours before removal to the lower temperature. The effect of a somewhat similar high-temperature treatment on a control was no less striking. It is evident that the time required for the maximum amount of control to be exhibited by sulphur fungicides under these conditions is markedly influenced by temperature.

Little infection occurred even in the case of the control when inoculated foliage was washed at the time of inoculation or shortly after (Table 4, Ser. 1). Inoculated trees exposed 2 hours in the moist chamber had nearly all of the spores removed by washing, although the leaves were allowed to dry 1 hour before they were washed (Table 4, Ser. 2). It is evident that after 3 hours or longer in the moist chamber, washing removed decidedly fewer spores. In the case of a heavier inoculation more spores adhered, though the general trend was the same (Table 4, Ser. 3). The spores were more adhesive when the leaves were dried 1 hour before washing (Table 4, Ser. 3). It would seem to follow that at about this time appressoria or attachments had developed. From these and other data it appears that the length of time after inoculation during which the spores may be washed off is variable. This probably is because of variations in the position of the spores in relation to the leaf surface, the condition of the spores, the type of foliage, and other environmental conditions.

Relation of the rate of drying of lime sulphur plus arsenate of lead spray to its effectiveness. In tests with the conidia of *Venturia inaequalis* in the laboratory, Doran (10) found that when lime-sulphur sprays were dried rapidly, undecomposed polysulphides were present and spore germination was prevented. However, if desiccation was slow, the polysulphides

were completely decomposed and the preparations were only slightly toxic or nontoxic under the conditions of his experiments. Butler and Doran (8) reported that sulphides were absent from lime sulphur 1–40, which had been held in a moist chamber at room temperature 3½ hours. High humidity, which checked evaporation, hastened decomposition.

The data of table 2 (Ser. 28, 29) are in agreement with Doran's report in that there was reduced effectiveness with slow drying. The treatments were made following periods of 66 to 72 hours, respectively, in the moist chamber after inoculation began. Lime sulphur 1–40 plus arsenate of lead 1–50, dried with a fan after application, showed increased effectiveness as compared with similar treatments allowed to dry in the greenhouse or kept in the moist chamber a short time after application. Incubation of the treated trees in the moist chamber at 10° C. for 2 to 4 hours apparently inhibited the toxic action. It appears, therefore, that the amount of moisture or humidity present during the early period after application of the spray is a factor in its effectiveness when applied after inoculation.

Relation of alkalinity to the initial effectiveness of the sprays containing lime sulphur. Foreman (12) concluded that free "alkali soda" is the most potent fungicidal agent of liver of sulphur. Eyre and Salmon (11) were unable to substantiate this contention. They found a solution containing 0.5 per cent caustic soda plus 1 per cent soft soap to be nonfungicidal against *Sphaerotheca humuli*. Barker, Gimingham, and Wiltshire (2) reported that it is not the alkalinity of the sulphide or the polysulphides of sodium that gives them their toxicity, although they stated that it may aid the toxic action. Young (61) suggested that the initial toxicity of lime-sulphur mixtures may be due partly to alkalinity or free hydroxyl ions. He reported the alkalinity of 1 part of lime sulphur diluted with 6 parts of water to be above pH 10. The data of Young (61) show that there was almost no germination for *S. cinerea* at pH 7.4 in a buffered mixture. He reported that the lime sulphur 1–6 changes from pH 10 to pH 6.4 in 2 hours if exposed to air, but may not change below pH 10 for 6 hours or longer if kept moist.

Sodium hydroxide, N/10 solution (Table 2, Ser. 12, 25, 28) and sodium hydroxide N/14 solution (Table 2, Ser. 16, 25) were strikingly effective and compared favorably with sprays containing lime sulphur when applied 16 to 66 hours after inoculation began. A moist treatment of 18 hours did not significantly affect the amount of control exhibited by sodium hydroxide N/10 solution (Table 2, Ser. 12). It is apparent that, at least as far as the effectiveness of lime sulphur applied after inoculation is concerned, alkalinity is probably an important factor in its toxicity.

Relation of the addition of lime to the effectiveness of certain sulphur fungicides. Swingle (49) reported that in storage varying quantities of

calcium arsenate are formed in different sulphur-lead-arsenate-lime dusts and that all the hydrated lime not reacting with the sulphur or lead arsenate is converted into calcium carbonate within one year or less. He concluded from chemical analysis that little or no change in fungicidal value should be expected. Reports vary as to whether or not the addition of lime to lime sulphur plus arsenate of lead increases or decreases its fungicidal value. As a result of a limited number of germination tests made on glass slides with the spores of *Sclerotinia fructigena* and of certain field tests, Wallace, Blodgett, and Hesler (56) were convinced that the addition of lime does not affect the efficiency of lime sulphur and lime sulphur plus arsenate of lead solutions to any marked degree. Robinson (46) reported that the addition of lime to a lime sulphur-arsenate of lead solution prevented arsenic from going into solution as a soluble salt and decreased the loss in polysulphides, thereby preserving the fungicidal properties of the lime sulphur. Thatcher and Streeter (50 state that hydrated lime prevented the chemical reactions which take place when arsenate of lead is added to lime sulphur. In their estimation these reactions reduce the fungicidal efficiency of the mixture. There appears to be no doubt that the addition of lime to the lime-sulphur-arsenate of lead preparation reduces the amount of water-soluble arsenic by the production of insoluble basic calcium arsenate, as shown by Mogendorff (37), Ginsburg (15), Van Der Meulen and Van Leeuwen (53), and Goodwin and Martin (23).

Hydrated or stone lime 3–50, applied as spray, 16 to 90 hours after inoculation and followed by moist treatments ranging from 10 to 13 hours, may exhibit fungicidal properties of their own under certain conditions (Table 2, Ser. 6, 16, 31). Indications were that the effectiveness of at least the stone lime was dependent in part upon the moist treatment following the application (Table 2, Ser. 16). Lime, whether hydrated or stone, exhibited for the most part comparatively little toxicity when applied as a spray before inoculation (Table 6, Ser. 8–10, and Table 7, Ser. 3, 4). Kolotex 8–50, applied with lime 3–50 as a spray after an infection period of 72 hours, was distinctly more effective than Kolotex, applied as a dust (Table 2, Ser. 36). The application of lime sulphur 1–40 plus arsenate of lead 1–50 and lime 3–50, following infection periods of from 66 to 90 hours, would indicate that on the average the lime did not materially decrease the effectiveness of lime sulphur plus arsenate of lead (Table 2, Ser. 28, 30, 31).

Relation of the addition of arsenate of lead to the effectiveness of lime sulphur and certain sulphur dusts. Morse (39, 40, 41) found that under favorable circumstances arsenate of lead has fungicidal value for the control of *Venturia inaequalis* under field conditions. However, as shown by Pickett et al. (43), Wallace (55), Morse (41), and Morse and Folsom (42),

arsenate of lead, although exhibiting fungicidal properties, is not satisfactory as a fungicide. It would appear that the effectiveness of arsenate of lead is dependent on the severity of the epiphytotic. Tests made in the laboratory with *V. inaequalis* by Shapovalov (Morse, 39), Wallace, Blodgett, and Hesler (56), and Butler and Doran (8) confirmed the conclusions to be drawn from field experiments that arsenate of lead is not completely effective at the strength used in orchard spraying.

Wallace, Blodgett, and Hesler (56) proved conclusively that the addition of lead arsenate does not decrease the fungicidal value of lime-sulphur solution but greatly increases it. Their tests were made in the laboratory with the conidia of *Venturia inaequalis*, *Sclerotinia fructigena*, and *Sphaeropsis malorum* Adehr., while the field tests were conducted to control *V. inaequalis* and *V. pyrina* Aderh. Bradley and Tartar (5) and several other workers have determined that soluble arsenic is formed in mixtures of lime sulphur and acid lead arsenate. More recently it has been reported by Goodwin, Martin, and Salmon (18) that solutions of calcium polysulphide and lead arsenate containing 0.204 per cent arsenic pentoxide are fungicidal. Butler and Doran (8) conducted experiments on glass with the spores of *V. inaequalis*, which show that the toxic properties of lime-sulphur solution are increased by the addition of arsenate of lead and that this in all probability is because of soluble arsenic. Marked increase in toxicity was obtained by the addition of arsenious oxide to the 1 in 40 lime-sulphur solution. They found that lead arsenate increases the toxicity of lime-sulphur solution decidedly more than calcium arsenate. Goodwin, Martin, and Salmon (18, 19) suggested that the increased fungicidal properties of the mixed lime-sulphur-lead arsenate spray are due to the presence of calcium thioarsenates together with calcium arsenates. Smith (47) presented data to show that the excretions from leaves containing large quantities of salts are significant factors in increasing the water-soluble arsenic content of sprays containing arsenical compounds. He found that all plants do not excrete the alkaline salts responsible for this change. This effect of alkaline salts is supported by the work of Mogendorff (37) and others cited by him. Ginsburg (13) reported that apparently high humidity, intense sunlight, and a high temperature acting separately or together do not play any significant rôle in the liberation of water-soluble arsenic. Mogendorff (37) found that water-soluble arsenic was formed when lead arsenate and sulphur flour were stored dry for 1 year. However, Ginsburg (15) reported that sulphur alone does not materially influence the decomposition of acid-lead arsenate.

In the present work arsenate of lead 1–50 or 2–50 was relatively ineffective when applied before inoculation (Table 6, Ser. 8, 10). Arsenate of lead used separately as a spray after infection periods of 16 to 72 hours was

not strikingly effective (Table 2, Ser. 2, 3, 11, 16). The fungicidal effect of arsenate of lead may be increased by a moist treatment after inoculation. The addition of arsenate of lead to Kolodust (Kolotex) may show an actual decrease in control as compared to Kolodust alone when applied after an infection period of 46 hours without a subsequent moist treatment (Table 2, Ser. 2). However, a marked increase in effectiveness for sulphur dusts containing arsenate of lead occurred when moist treatments of 15 to 20 hours followed the applications to foliage after infection periods of from 15 to 48 hours (Table 1, Ser. 12–14, and Table 2, Ser. 10, 11).

The effectiveness of calcium monosulphide, when applied after infection periods of from 28 to 35 hours, also was increased by the addition of arsenate of lead (Table 2, Ser. 9, 17, 34). The data of table 2 (Ser. 2, 7, 8, 11, 18, 19, 24, 32–35), where all the series except 2 and 24 were given periods in the moist chamber of rfom 10 to 20 hours and where lime sulphur 1–40, with and without arsenate of lead 1–50, was applied after infection periods of from 28 to 90 hours, show a similar trend of increased fungicidal effectiveness resulting from the addition of arsenate of lead. While the addition of calcium arsenate 1–50, (Table 2, Ser. 18–21) to lime sulphur 1–40, 60 to 82 hours after inoculation, did not increase its effectiveness as did the arsenate of lead, it did markedly increase the toxicity when the applications were followed by moist treatments of 8 to 12 hours. The results obtained from the use of basic arsenate of lead were not widely different from those secured with the addition of acid arsenate of lead (Table 2, Ser. 32). However, this test was too limited to be conclusive.

From a limited series of experiments (Table 2, Ser. 32–35), conducted to gain evidence on the part played by soluble arsenic in the fungicidal action of lime-sulphur spray containing arsenate of lead, it appears that if As_2O_5 is added in sufficient quantity it can increase the efficiency of the lime-sulphur spray as much as the addition of arsenate of lead. The addition of 0.01 per cent As_2O_5 to lime sulphur 1–40 did not increase its toxicity (Table 2, Ser. 32). Very little increased fungicidal action resulted when 0.02 per cent As_2O_5 was added to lime sulphur 1–40 and applied 48 hours after inoculation (Table 2, Ser. 33). However, 0.02 per cent of As_2O_5 was apparently as effective as arsenate of lead 1–50 in increasing the toxicity of lime sulphur 1–40, applied after an infection period of 28 hours (Table 2, Ser. 34). The addition of 0.03 per cent of As_2O_5 to lime sulphur 1–40 was likewise as effective as arsenate of lead 1–50 in increasing the fungicidal action of lime sulphur when applied 35 hours after inoculation (Table 2, Ser. 35). The As_2O_5, 0.03 per cent, was as effective alone as the lime sulphur 1–40 (Table 2, Ser. 35). There was no host injury when 0.04 per cent As_2O_5 was added to the lime sulphur 1–40. Unless otherwise stated, sterile distilled water was used in the preparation of the spray

materials in these experiments. When alkaline water is used, less soluble arsenic in the spray would be expected. Table 2 (Ser. 20, 21) and other data tend to show that the alkalinity of the water used in the preparation of lime sulphur 1–40 plus arsenate of lead 1–50 or calcium arsenate 1–50 was a factor in reducing fungicidal effectiveness when applied after infection periods of from 60 to 75 hours. The spray prepared from lake water, about pH 8, tended to be less toxic than that made with distilled water of about pH 5.7.

Relation of the addition of some spreaders and adhesive materials to the effectiveness of certain fungicides—Casein lime.—Thatcher and Streeter (50) found that the addition of casein-containing preparations effectively prevents the chemical change that occurs when acid lead arsenate is mixed with lime-sulphur solution. They reported that the data available from orchard experiments indicate that there is little likelihood of a reduction in the insecticidal and fungicidal effectiveness of the combined lead arsenate and lime-sulphur sprays as a result of its use. Mogendorff (37) and Ginsburg (15) pointed out that the addition of calcium caseinate to acid lead arsenate spray increases the water-soluble arsenic content. The former found, however, that the decomposition of the lead arsenate was greatly diminished and that in a complete dry mix spray the presence of the casein-lime spreader together with the lime and sulphur greatly reduces the amount of soluble arsenic. In interpreting this he suggested that chemical action is lessened by the spreader which has enveloped the arsenate of lead or sulphur particle, as the case may be. In certain tests against the powdery mildew of hops Goodwin, Martin, and Salmon (20) obtained an increase in the effectiveness of sulphur with the addition of casein lime.

Kolotex 8–50 and Kayso (casein lime) ½–50, applied together as a spray after an infection period of 72 hours, were somewhat more effective than Kolotex used alone as a dust (Table 2, Ser. 36), although it is doubtful whether this difference is significant. The addition of Kayso ½–50 to lime sulphur 1–40 plus arsenate of lead 1–50 seemed to increase the effectiveness when applied 72 to 90 hours after inoculation began (Table 2, Ser. 29–31). Lime sulphur plus Kayso plus arsenate of lead appeared to be consistently superior in varying degrees to lime sulphur plus arsenate of lead and more effective than mixtures prepared in the following order: lime sulphur plus arsenate of lead plus Kayso and Kayso plus arsenate of lead plus lime sulphur.

Emulsified Oil[6]

The possible value of emulsified oil as an orchard spray has been investigated chiefly by entomologists. A noninjurious effective insecticidal and

[6] Investigations relative to some limiting factors in the use of saturated petroleum oils are reported by Knight, Chamberlin, and Samuels (31).

fungicidal emulsified oil for summer spraying is still in the developmental stage. Emulsified oil L202 seemed to be comparable with Bordeaux mixture and superior to certain sulphur dusts when applied 46 to 72 hours after inoculation (Table 2, Ser. 1, 3, 4). However, situations may arise in which emulsified oil L20 is ineffective after infection periods of from 24 to 30 hours (Table 2, Ser. 38–40). L205,[7] an emulsified oil containing a form of sulphur, applied 24 to 72 hours after inoculation, apparently did not offer such good control as the sprays containing lime sulphur but seemed to be more effective than oil emulsion alone, certain sulphur dusts, finely divided sulphur sprays, and Bordeaux mixture (Table 2, Ser. 1–4, 38–40). L205 may not be so toxic in some instances, even when applied a comparatively short time after inoculation (Table 2, Ser. 38–40). Kolodust 8–50 (Table 2, Ser. 1, 3, 37), Kolotex 8–50 (Table 2, Ser. 4, 36), and Bentonite sulphur 5–50 (Table 2, Ser. 38), applied in a 2 per cent emulsified oil, L202 or L20, after infection periods of 30 to 72 hours, were decidedly more efficient than when used alone as dusts or sprays. These combinations are not quite so effective in post-infection treatments as L205 but, as shown later, are more adhesive. K–1–CB, 117C, 117E, and 118, which are mercurial compounds, may be decidedly effective as fungicides in the 2 per cent oil emulsion L20, when applied 24 to 30 hours after inoculation (Table 2, Ser. 34, 38–40).

Soft Soap

Goodwin and Salmon (22) found that sulphur in suspension in a solution of soft soap gives more rapid and complete control of *Sphaerotheca humuli* than sulphur used as a dust. Goodwin, Martin, and Salmon (20) are of the opinion that soft soap not only gives improved dispersion but increases the fungicidal action of sulphur by virtue of its alkalinity, which hastens the hydrolysis of the sulphur.

Experiments were conducted in which Kolodust 8–50 (Table 2, Ser. 37), Kolotex 8–50 (Table 2, Ser. 36), and Bentonite sulphur 5–50 (Table 2, Ser. 38), respectively, were applied in a solution of 1 per cent soft soap, following infection periods of 48, 72, and 30 hours, respectively. The data show a distinct increase in effectiveness for this combination as compared with the sulphur dusts used alone. Soft soap is in the majority of cases more effective than oil emulsion in this particular kind of test. Neutral sodium and potassium soft soaps exhibit fungicidal properties (Table 2, Ser. 6, 16, 38).

RELATION OF THE DISTRIBUTION OF CERTAIN FUNGICIDES TO THEIR EFFECTIVENESS

The rate of growth of the host or the amount of unprotected susceptible foliage, flowers, and fruit throughout the season, under varying environ-

[7] L205 has been found to cause injury under certain conditions in the field.

mental conditions, is an important factor to be considered in spraying and dusting programs. Inasmuch as sulphur may be effective across space, the question arises as to the relation of degree of coverage of apple foliage to the amount of infection.

The fungicidal action of sulphur across space. That the germination of spores is inhibited even when they are not in direct contact with sulphur particles has been demonstrated frequently. In the progress report of Barker, Gimingham, and Wiltshire (2) it was shown that sulphur could exercise a definite toxic influence on a living fungus spore over considerable distances. Young (61) attributed the inhibition of germination of fungus spores to pentathionic acid, which he stated is volatile. Barker (3, 4) claimed to have proved conclusively that free sulphur from any of the ordinary forms of sulphur is dispersed through space in the form of minute solid particles and that this emanation is continuous under suitable moisture and temperature conditions. From further investigations Barker (4) reports that sulphuretted hydrogen is formed as the direct result of interaction between the sulphur and the host plant or the fungus at ordinary temperatures. Marsh (34), working in the same laboratory, concluded that this gas has considerable fungicidal action and that the quantity formed by living sulphured leaves was definitely toxic under the conditions of his experiments and might be a factor of importance in the greenhouse. Goodwin and Martin (24) claimed that sulphur vaporizes and condenses as minute solid particles.

TABLE 5.—*The effectiveness of Kolodust in controlling Wealthy apple leaf infection by the ascospores of Venturia inaequalis by fungicidal action across space*

Series and date	Inoc. chamber		Fungicide[a]	Trees inoc.	Final results average per tree	
	Temp.	Period in			Leaves infected	Lesions per leaf
	°C.	Hrs.		No.	No.	No.
1927						
Series 1[b]						
June 17	18	35	Untreated	3	2.7	41.5
"	18	35	Kolodust (8–50)	4	0.2	1.2
Series 2[b]						
June 19	23	24	Untreated	3	4.0	11.2
"	23	24	Kolodust (8–50)	4	0.5	3.0
1928						
Series 3[c]						
May 5	10	40	Untreated	3	12.3	17.6
"	10	40	Kolodust (8–50)	4	3.3	3.2

[a] Strips of cheesecloth dipped in a suspension of sulphur were hung about the trees during the infection period in the moist chamber. Care was taken to avoid any contact between these strips and the trees.

[b] Conidial inoculum of *Venturia inaequalis* from leaves in the orchard.

[c] Ascosporic inoculum of *Venturia inaequalis* from overwintered apple leaves.

TABLE 6.—*The relation of degree of coverage of Wealthy apple foliage to the effectiveness of certain fungicides against infection by the ascospores of Venturia inaequalis*

Series and date	Inoc. chamber		Fungicide[a]	Final results averaged per twig	
	Temp.	Period in		Leaves infected	Lesions per leaf
	°C.	Hrs.		No.	No.
1927					
Series 1[b]					
June 30	20	24	Untreated	4.2	56.0
"	20	24	L–S 1–40 + AL 1–50	0.3	1.5
"	20	24	S–Ars dust 90–10	1.0	5.0
Series 2[b]					
July 1	20	24	Untreated	4.0	70.6
"	20	24	L–S 1–40 + AL 1–50	0.0	0.0
"	20	24	S–Ars dust 90–10	0.3	2.0
Series 3[b, c]					
July 15	23	24	Untreated	3.0	20.3
"	23	24	L–S 1–40 + AL 1–50	0.3	0.5
"	23	24	S–Ars dust 90–10	0.3	1.3
Series 4[b, c]					
July 19	23	24	Untreated	3.0	14.7
"	23	24	L–S 1–40 + AL 1–50	0.8	1.8
"	23	24	S–Ars dust 90–10	1.0	4.3
1928					
Series 5[d]					
Mar. 22	24	24	Untreated	3.0	70.3
"	24	24	L–S 1–40 + AL 1–50	0.0	0.0
"	24	24	L–S 1–40 + AL 1–50[e]	1.0	3.0
"	24	24	Kolotex	1.0	2.3
"	24	24	Kolotex[e]	1.6	4.4
Series 6[d]					
May 3	20	40	Untreated	4.8	51.8
"	20	40	BM 4–4–50	0.8	0.9
"	20	40	Kolodust	0.5	0.2
Series 7[d]					
May 5	10	40	Untreated	4.1	32.2
"	10	40	BM 4–4–50	0.8	0.5
"	10	40	Kolodust	1.0	0.8
1929					
Series 8[d]					
Feb. 15	20	48	Untreated	3.7	69.7
"	20	48	Untreated[e]	3.0	7.0
"	20	48	BM 4–4–50[f]	3.0	1.2
"	20	48	BM 4–4–50[g]	0.3	0.7
"	20	48	Untreated[e]	3.0	21.0
"	20	48	Lime 4–50[f]	3.0	7.3
"	20	48	Lime 4–50[g]	4.0	53.5
"	20	48	Untreated[e]	3.0	10.3
"	20	48	L20 2%[f]	3.0	3.0
"	20	48	L20 2%[g]	0.5	3.0
"	20	48	AL 2–50[g]	2.5	45.0

TABLE 6—(*Continued*)

Series and date	Inoc. chamber		Fungicide[a]	Final results averaged per twig	
	Temp.	Period in		Leaves infected	Lesions per leaf
	°C.	Hrs.		No.	No.
Series 9[d]					
Mar. 9	15	40	Untreated	4.3	76.7
"	15	40	Untreated[e]	3.5	42.1
"	15	40	BM 4–4–50[f, h]	3.5	10.0
"	15	40	Untreated[e]	3.0	54.7
"	15	40	Stone lime 4–50[f]	3.0	45.2
Series 10[d]					
Apr. 2	15	45	Untreated	4.2	85.5
"	15	45	Untreated[e]	2.8	19.8
"	15	45	BM 4–4–50[f, h]	2.8	3.6
"	15	45	Untreated[e]	3.5	39.8
"	15	45	Stone lime 4–50[f]	3.5	33.4
"	15	45	Stone lime 4–50[g]	4.3	59.0
"	15	45	AL 1–50[g]	3.5	38.0

[a] L-S = Commercial liquid lime sulphur. AL = Commercial powdered arsenate of lead. BM = Bordeaux mixture. L20 = Emulsified oil. Three leaves were treated for each twig.

[b] The trees were inoculated with conidia of *Venturia inaequalis* obtained from leaves in the orchard.

[c] The treated areas were delimited by cocoa butter.

[d] The trees were inoculated with the ascospores of *Venturia inaequalis* from overwintered apple leaves.

[e] One-half of the treated leaves was left as a control.

[f] The treatments were applied to only one side of the leaf (c).

[g] The foliage was completely covered by treatments.

[h] Stone lime was used in preparation of Bordeaux mixture.

Trees previously inoculated with the imperfect or perfect stage of *Venturia inaequalis* were placed in the center of the moist chamber (Fig. 1), a structure having a capacity of 130.5 cu. ft. inside the curtains. Within this space pieces of cheesecloth (183 sq. ft. in all) were suspended from the framework on two sides of the trees but not touching them. This material previously had been dipped in a water suspension of Kolotex 8–50 and had taken up between 70 and 100 grams of the sulphur. Strips treated in this manner were used dry or wet. Considerable control of the fungus was obtained (Table 5). As is to be expected, however, some infection occurred. This may occur in any of the experiments, for invariably a certain number of spores are much more resistant than others or more advantageously placed for infection. This would be quite manifest in such a delicate test. Sulphur appears to have been toxic under these conditions with infection periods of 24 to 40 hours at temperatures ranging from 10° to 23° C. Although the plants were not incubated at these temperatures, it is not probable that with infection periods of this duration the "con-

densed" particulate sulphur would be effective to such a degree after the trees were removed to the greenhouse.

The relation of degree of coverage of apple foliage to amount of infection. The fungicides were applied in about $\frac{1}{8}$ inch bands evenly spaced transversely across each leaf. The area covered varied with the size of the leaves, each leaf usually receiving two or three bands. In some instances areas about $\frac{1}{4}$ inch square were treated at suitable intervals on the leaf or arranged in such a manner as to give fairly large unprotected areas. The results appear in table 6. It is quite evident that sulphur-arsenate dust 90–10 (Ser. 1–4); Kolotex (Ser. 5); Kolodust (Ser. 6, 7); lime sulphur 1–40 plus arsenate of lead 1–50 (Ser. 1–5); and Bordeaux mixture (Ser. 6–10) gave good control when present in restricted areas at a temperature range of 10° to 24° C. Except in an occasional experiment, as in series 8, lime 4–50 (Ser. 8–10) did not exhibit any appreciable toxicity, regardless of whether the treatment was applied as bands or complete coverage. Hydrated and stone lime were equally ineffective when applied in these ways. The effectiveness of the Bordeaux mixture was not altered when stone lime was used instead of hydrated lime. The concentrations of the material tested in the bands, within limits, did not appear to influence the degree of toxicity of the treatments. L20, an emulsified oil, seemed markedly effective when applied to limited areas on the leaf surface (Ser. 8). Complete coverage with arsenate of lead did not appreciably inhibit infection (Ser. 8, 10). Good infection occurred on untreated leaves above and below the treated leaves in all the series (Table 6) and on untreated halves of leaves in those series where only one-half was treated (Ser. 8–10).

In an attempt to limit the possible spread of the sulphur preparations used incident to water movements on the leaf, a series of experiments was conducted in which the areas to which the fungicide was applied were delimited by means of cocoa butter. The efficiency of the sulphur fungicides was not appreciably decreased (Ser. 3–5). The data on this point are not fully conclusive, however, because the growing leaves in some cases cracked the cocoa butter before the trees were removed from the moist chamber.

Apparently temperature did not materially change the effectiveness of the sulphur fungicides within the range of 10° to 24° C. The spores of the imperfect and perfect stages of the fungus were affected similarly.

Inasmuch as it was found that sulphur was effective over a larger area than was actually treated, rapidly growing apple trees were dusted or sprayed and after a certain amount of growth had taken place were inoculated with *Venturia inaequalis*. In nearly every case treatments with the sulphur fungicides, such as Kolodust, Kolotex, and lime sulphur 1–40 plus arsenate of lead 1–50, protected even the smallest leaf measurable at the

TABLE 7.—*The relative efficiency of certain fungicides in protecting rapidly growing Wealthy apple leaves against infection by the ascospores of Venturia inaequalis*

Series and date	Fungicide[a]	Inoculation chamber			Leaf size when fung. app.	Leaf size at end of infection period	Lesions per leaf
		Date	Temp.	Period in			
			°C.	Hrs.	Mm.	Mm.	No.
1927							
Series 1[b]							
June 25	Kolodust	June 30	20	24	?	7 x 25	0
					?	17 x 40	13
					?	22 x 50	0
					6 x 20	27 x 60	0
					10 x 20	31 x 55	0
"	L-S 1–40 + AL 1–50	"	20	24	?	12 x 32	5
					?	20 x 42	10
					?	30 x 55	0
					15 x 30	42 x 60	0
					35 x 58	47 x 70	0
1928							
Series 2[c]							
Mar. 14	Kolotex	Mar. 19	5	24	?	9 x 20	0
					?	17 x 35	17
					?	24 x 48	0
					12 x 24	30 x 55	0
					24 x 43	40 x 73	0
"	L-S 1–40 + AL 1–50	"	5	24	?	12 x 28	3
					?	18 x 37	0
					13 x 30	30 x 60	0
					20 x 50	40 x 83	0
Series 3[c,d]							
May 21	BM 4–4–50	May 26	16	42	?	?	26
					?	14 x 34	62
					?	24 x 50	n

TABLE 7.—(*Continued*)

Series and date	Fungicide[a]	Inoculation chamber			Leaf size when fung. app.	Leaf size at end of infection period	Lesions per leaf
		Date	Temp.	Period in			
			°C.	Hrs.	Mm.	Mm.	No.
					?	28 x 62	n
					16 x 35	42 x 72	40
					25 x 55	53 x 95	60
"	Kolodust	"	16	42	?	?	34
					?	15 x 34	70
					?	20 x 50	13
					13 x 28	35 x 60	0
					15 x 35	40 x 70	0
"	Lime 4–50	"	16	42	?	?	34
					?	22 x 50	n
					30 x 55	35 x 65	n
					24 x 48	45 x 80	70
Series 4[c]							
Feb. 27	Untreated	Mar. 1	15	35	?	?	2
					?	12 x 32	42
					10 x 32	20 x 49	70
					18 x 37	27 x 52	33
"	BM 4–4–50	"	15	35	?	14 x 31	17
					10 x 30	18 x 44	6
					15 x 42	24 x 52	6
"	Lime 4–50	"	15	35	?	?	7
					?	13 x 40	36
					14 x 38	22 x 57	n
					21 x 50	30 x 68	n
"	L20 2%	"	15	35	?	?	3
					?	12 x 32	1
					10 x 32	20 x 49	12

TABLE 7.—(*Continued*)

Series and date	Fungicide[a]	Inoculation chamber			Leaf size when fung. app.	Leaf size at end of infection period	Lesions per leaf
		Date	Temp.	Period in			
			°C.	Hrs.	Mm.	Mm.	No.
					18 x 37	27 x 52	27
1929							
Series 5[c]							
Apr. 2	Untreated	Apr. 5	15	45	?	?	6
					?	?	9
					?	21 x 48	n
					12 x 32	28 x 58	n
					17 x 42	35 x 68	n
"	BM 4–4–50[e]	"	15	45	?	?	2
					?	22 x 50	56
					13 x 35	26 x 60	14
					20 x 51	41 x 76	3
"	Untreated	Apr. 7	15	45	?	?	23
					?	?	59
					?	?	52
					10 x 30	37 x 75	n
					16 x 40	42 x 84	14
"	BM 4–4–50[e]	"	15	45	?	?	27
					?	?	n
					?	?	n
					11 x 30	38 x 77	14
					20 x 43	50 x 90	0

[a] L-S = Commercial liquid lime-sulphur. AL = Commercial powdered arsenate of lead. BM = Bordeaux mixture. L20 = Emulsified oil.

[b] The trees were inoculated with the conidia of *Venturia inaequalis* from leaves in the orchard.

[c] The trees were inoculated with the ascospores of *Venturia inaequalis* from overwintered apple leaves.

[d] Measurements were not made until May 28.

[e] Stone lime was used in the preparation of the Bordeaux mixture.

time of application throughout its period of growth (Table 7, Ser. 1–3). Frequently, a leaf younger than the smallest one measured also was protected. The period between fungicidal treatment and inoculation was usually 4 or 5 days. The effectiveness of the sulphur fungicides did not seem to be influenced to any marked degree by temperature within the range of 5° to 20° C. Both the imperfect and perfect stages of the fungus were tested with like results. That the trees were susceptible was evidenced to some degree by the infection of the unprotected leaves and the excellent infection on control trees. Bordeaux mixture may be remarkably effective in similar applications but in less degree than the sulphur (Table 7, Ser. 3–5). The Bordeaux mixture was equally effective whether hydrated or stone lime was used. Hydrated and stone lime were not effective in experiments similar to those in which Bordeaux mixture was used (Table 7, Ser. 3, 4). Plants were treated, respectively, with hydrated and stone lime and Bordeaux mixture made from each and placed at a temperature of 28° C. with relative humidities of 50 and 75 per cent. The results were not materially different from those obtained when treated plants were placed in the greenhouse until inoculation. Oil emulsion L20 was somewhat less effective than Bordeaux under the same conditions (Table 7, Ser. 4). These results with Bordeaux mixture seem to have considerable theoretical and practical interest. However, a more detailed treatment of the questions they raise lies beyond the scope of the present investigations.

THE EFFECTIVENESS OF CERTAIN FUNGICIDES FOR INACTIVATING THE CONIDIAL INOCULUM IN THE CONTROL OF VENTURIA INAEQUALIS

Field observations by Keitt and Jones (29) and others show that the development of sufficient secondary inoculum, followed by the cooler weather and increased atmospheric moisture that may occur later in the season, can initiate late infection of fruit and more abundantly establish the fungus on the foliage. This increased leaf infection is an important factor in providing a greater source of inoculum in the following year (Wilson, 59). Applications of dusts and sprays have been recommended for some time to prevent late infection. In the present study inquiry has been made into the effectiveness of certain fungicides in inactivating the conidia that are present and preventing further production of conidia.

Fungicides applied to well-developed apple-scab lesions in orchard foliage were found to be not only toxic to the spores present but able to prevent further sporulation of the mycelia for a considerable length of time, or actually to kill the fungus in these lesions. The effectiveness of the fungicide apparently was influenced by the type of lesion, the degree of moisture, or by both moisture and temperature. The results presented in figure 4, together with other data, show that sulphur-arsenate dust 90–10,

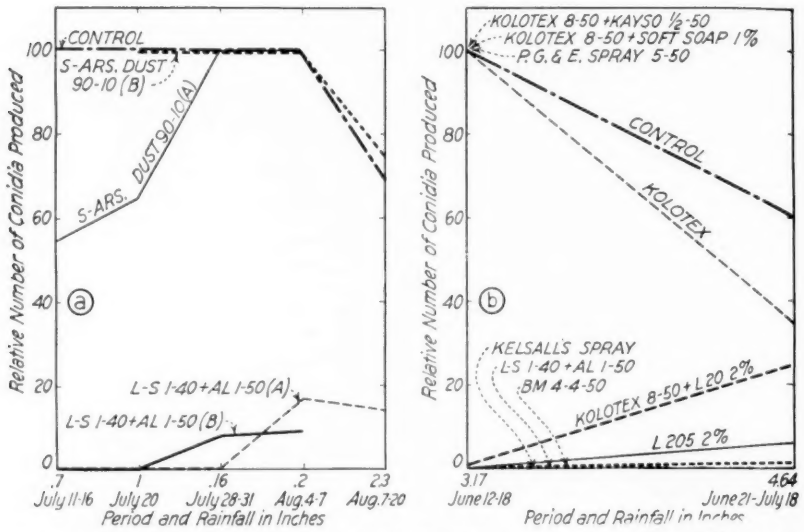

FIG. 4. Effectiveness of certain fungicides for inactivating the conidial inoculum in the control of *Venturia inaequalis*. The relative number of conidia produced on the untreated and treated leaves was determined about 3 days after each rain. Severely scabbed leaves were selected and thoroughly atomized to remove spores. Estimates of the number of spores in the washings were made by a standardized technique. Relative numbers were assigned, based on the control which is taken as 100. S-Ars. dust = Sulphur arsenate dust 90–10. L-S = Commercial liquid lime sulphur. AL = Commercial powdered arsenate of lead. Kayso = Casein lime. Soft soap = Neutral sodium soft soap (20th Century Soap). P. G. & E. spray = Prepared from a finely divided sulphur paste. Kelsall's spray = Lime sulphur-aluminum sulphate mixture. BM = Bordeaux mixture. L20 = Emulsified oil. L205 = L20 plus a form of sulphur.

applied to well-developed lesions did not inhibit production of conidia after 0.15 inch of rainfall and that there was little or no toxic effect from the treatment after 1 inch of rainfall. Kolotex and P. G. & E. sulphur paste 5–50, both of which contain finely divided sulphur, were apparently little more efficient than the coarser sulphur-arsenate dust 90–10. The addition of soft soap, 1 per cent, or Kayso ½–50 to Kolotex 8–50 did not seem to make the dust markedly more efficient, but the addition of 2 per cent of an emulsified oil, L20, gave increased effectiveness. The sprays Bordeaux mixture 4–4–50, lime sulphur-aluminum sulphate mixture, lime sulphur 1–40 plus arsenate of lead 1–50, and L205, 2 per cent, appeared appreciably to prevent the development of viable conidia even after 7.81 inches of rainfall, and, with the possible exception of the oil spray L205, they may be effective for the greater part of the season, depending on environmental factors. In addition, they may entirely kill the fungus in the lesions, but, as previously mentioned, this action is influenced by various factors. The

toxicity of lime sulphur plus arsenate of lead appreciably increased when the application was followed by rain or dews and a favorable temperature. Frequent rains together with other environmental factors have a marked effect on the quantity of conidia produced by nontreated lesions. From these data it appears that the secondary inoculum of *Venturia inaequalis* may be appreciably reduced according to the fungicidal effectiveness and adhesiveness of the treatments.

RELATION OF WASHING TREATMENTS TO THE EFFECTIVENESS OF CERTAIN FUNGICIDES[8]

In the study of the effectiveness of sprays and dusts one is confronted with the problem of duration of the period of protection per application. The data that have accumulated on this phase of the problem have been derived chiefly from three sources: laboratory studies, field studies, and chemical analyses of treated foliage. Laboratory studies may give comparative data but insufficient information as to what actually occurs in practice. Results of field investigations are often apparently contradictory, due, no doubt, to varying environmental conditions and other limiting factors. Chemical analyses of the treated foliage have given very valuable data but do not answer the question of whether or not foliage is adequately protected. The nature of the greenhouse facilities has enabled the writer to begin an investigation of this problem under partly controlled conditions. It was hoped that by treating the leaves of potted apple trees with various types of fungicides, subjecting them to a washing technique and finally inoculating them with ascospores of *Venturia inaequalis*, a more intimate knowledge could be obtained concerning the comparative effectiveness of materials in terms of disease control.

Apparatus and method. Potted Wealthy apple trees, as described on page 450, were used for these experiments. Specimens of equal or nearly equal height were selected for each experiment. At a suitable time after treatment the trees, with their tops at approximately the same level, were placed in a single row around the edge of a turntable situated in a moist chamber (Fig. 2, C). The turntable (Fig. 2, C) made 0.73 revolution per minute. A Skinner irrigation nozzle was placed about 5 feet above and a little to one side of the turntable. A rain gauge was placed between two of the trees, its aperture level with the top of the twigs, so as to obtain a record of the approximate amount of washing for the allotted time. The

[8] A literature review of spreaders and adhesives and a proposed theory of adherence will be found in the paper by Moore (38). Holland, Dunbar, and Gilligan (27) cite literature and give other data relative to wetting, spreading, and adhesiveness, and other properties of copper fungicides as influenced by the addition of various supplements.

TABLE 8.—*The relation of washing treatments to the effectiveness of certain fungicides in preventing infection of Wealthy apple leaves by the ascospores of Venturia inaequalis*

Series, date, and fungicides[a]	Washing treatment		Inoc. chamber		Final results averaged per twig			
	Amount	Time	Temp.	Period in	Leaves infected	Max. lesions on one leaf		Total lesions
	In.	Min.	°C.	Hrs.	No.	No.	Rel. No.	Rel. No.
Series 1[b], April 4, 1928								
Untreated	.....	.....	10	42	6.0	39.0	100	100
Kolotex	0.36	.....	10	42	0.0	0.0	0	0
"	0.50	.....	10	42	3.0	21.2	54	35
"	0.93	.....	10	42	1.5	6.9	18	9
"	1.08	.....	10	42	2.0	15.3	39	23
L-S 1–40 + AL 1–50	0.36	.....	10	42	0.0	0.0	0	0
"	0.50	.....	10	42	0.0	0.0	0	0
"	0.93	.....	10	42	0.0	0.0	0	0
"	1.08	.....	10	42	0.0	0.0	0	0
Series 2, May 16, 1928								
Untreated	2.00	60	20	40	3.0	22.3	100	100
" (not washed)	0.00	.....	20	40	1.6	3.3	15	12
Kolotex	2.00	60	20	40	0.8	1.5	7	4
"	4.00	120	20	40	3.0	25.3	113	99
Kolotex 8–50 + L20 2%	2.00	60	20	40	0.0	0.0	0	0
"	4.00	120	20	40	1.0	3.7	17	23
L205 2%	2.00	60	20	40	2.0	6.6	30	23
"	4.00	120	20	40	3.0	43.0	193	149
L-S 1–40 + AL 1–50	2.00	60	20	40	0.0	0.0	0	0
"	4.00	120	20	40	0.0	0.0	0	0
Series 3, May 19, 1928								
Untreated	1.00	25	15	42	4.8	97.8	100	100
Kolotex	1.00	25	15	42	3.0	69.3	71	69
"	2.00	50	15	42	5.3	90.0	92	87
Kolotex 8–50 + L20 2%	2.00	50	15	42	3.0	28.3	29	19
"	4.00	100	15	42	2.3	15.3	16	14
L-S 1–40 + AL 1–50	2.00	50	15	42	0.6	1.3	1	1
"	4.00	100	15	42	2.0	10.0	10	6
BM 4–4–50	2.00	50	15	42	3.6	7.3	7	7
"	4.00	100	15	42	3.6	44.0	45	42

TABLE 8.—(*Continued*)

TABLE 8.—(*Continued*)

Series, date, and fungicides	Washing treatment		Inoc. chamber		Final results averaged per twig			
	Amount	Time	Temp.	Period in	Leaves infected	Max. lesions on one leaf		Total lesions
	In.	Min.	°C.	Hrs.	No.	No.	Rel. No.	Rel. No.
L205 2%	2.00	50	15	42	3.4	24.0	25	20
"	4.00	100	15	42	4.6	100.0	102	93
K-1-GB 2–50	2.00	50	15	42	5.5	90.0	92	135
"	4.00	100	15	42	5.5	100.0	102	193
Series 4[c], May 24, 1928								
Untreated	6.00	15	17	48	3.5	27.0	100	100
" (not washed)	0.00		17	48	1.5	15.0	56	27
L-S 1–40 + AL 1–50	6.00	15	17	48	0.0	0.0	0	0
"	12.00	30	17	48	0.2	0.2	1	1
BM 4–4–50	6.00	15	17	48	2.4	6.8	25	17
"	12.00	30	17	48	1.7	1.7	6	7
L205 2%	6.00	15	17	48	4.0	37.0	137	109
"	12.00	30	17	48	4.0	46.7	173	154
Series 5, June 8, 1928								
Untreated	1.50	90	16	34	6.0	82.6	100	100
Kolodust	0.75	45	16	34	2.2	34.0	41	33
"	1.70	90	16	34	3.5	15.7	19	10
"	3.00	180	16	34	2.6	15.3	19	8
Kolodust 8–50 + soft soap 1%	1.50	90	16	34	2.7	20.7	25	13
"	3.00	180	16	34	3.0	29.3	35	17
Kolodust 8–50 + Kayso ½–50	1.50	90	16	34	3.2	16.7	20	12
"	3.00	180	16	34	3.0	29.7	36	20
Kolodust + Kayso 80–10	1.50	90	16	34	2.2	7.5	9	4
Kolodust 8–50 + L20 2%	1.50	90	16	34	0.4	2.6	3	1
"	3.00	180	16	34	1.2	2.5	3	2
Series 6, June 13, 1928								
Untreated	1.60	60	16	32	6.0	100.0	100	100
" (not washed)	0.00		16	32	3.8	10.6	11	9
Kolodust	1.60	60	16	32	3.5	42.3	42	40
"	3.10	120	16	32	2.0	8.3	8	2
P. G. & E. sulphur paste	1.60	60	16	32	4.5	74.0	74	55
"	3.10	120	16	32	4.7	72.0	72	34

TABLE 8.—(*Continued*)

Series, date, and fungicide[a]	Washing treatment		Inoc. chamber		Final results averaged per twig			
	Amount	Time	Temp.	Period in	Leaves infected	Max. lesions on one leaf		Total lesions
	In.	Min.	°C.	Hrs.	No.	No.	Rel. No.	Rel. No.
Ferrox sulphur paste 5–50	1.60	60	16	32	2.0	13.0	13	6
"	3.10	120	16	32	2.3	10.0	10	5
L-S 1–40	3.10	110	16	32	2.0	2.0	2	1
"	6.00	230	16	32	1.0	5.3	5	2
Series 7, June 16, 1928								
Untreated	2.00	120	17	46	5.0	95.0	100	100
L-S 1–40 + AL 1–50	2.00	120	17	46	0.2	0.2	0	0
"	4.00	240	17	46	1.0	0.7	1	0
"	6.00	360	17	46	0.0	0.0	0	0
"	8.00	480	17	46	0.7	0.7	1	0
BM 4–4–50	2.00	120	17	46	1.0	2.2	2	1
"	4.00	240	17	46	3.5	11.2	12	8
"	6.00	360	17	46	3.0	22.5	24	1
"	8.00	480	17	46	2.7	8.6	9	4
C-L-Ars. dust 10–80–10	2.00	120	17	46	2.3	10.3	11	6
"	4.00	240	17	46	4.0	74.5	78	42
"	6.00	360	17	46	4.0	69.3	73	45
Series 8, June 2, 1928								
Untreated	1.50	90	21	30	4.7	74.7	100	100
Pomodust	1.50	70	21	30	5.0	86.0	115	99
"	3.75	180	21	30	4.7	70.0	94	94
Pomodust 8–50 + Fe_2O_3 1%	1.50	90	21	30	3.7	31.7	42	26
"	3.25	180	21	30	4.7	96.7	129	153
Pomodust + Fe_2O_3 80–20	1.50	90	21	30	3.2	19.5	26	20
"	3.25	180	21	30	4.2	61.2	82	81
Pomodust (coated with Fe_2O_3 2%)	1.50	90	21	30	2.8	8.2	11	11
"	3.25	180	21	30	5.5	61.2	82	113
Fe_2O_3 1%	2.00	90	21	30	5.2	100.0	134	171
Pomodust 8–50 + L20 2%	2.00	90	21	30	0.5	0.2	0	0
"	3.75	180	21	30	4.0	47.0	63	58

[a] L-S = Commercial liquid lime sulphur. AL = Commercial powdered arsenate of lead. BM = Bordeaux mixture. C-L-Ars. = Copper-lime-lead arsenate. L20 = Emulsified oil. L205 = Emulsified oil plus a form of sulphur. K-I-GB = Proprietary mercury compound. Soft soap = Neutral sodium soft soap. Kayso = Casein lime. Pomodust (coated with Fe_2O_3 2%) = Pomodust was suspended in a 2 per cent solution of ferric oxide, dried and resifted.

[b] The washing was by natural rain.

[c] The regular nozzles of the chambers were running full force.

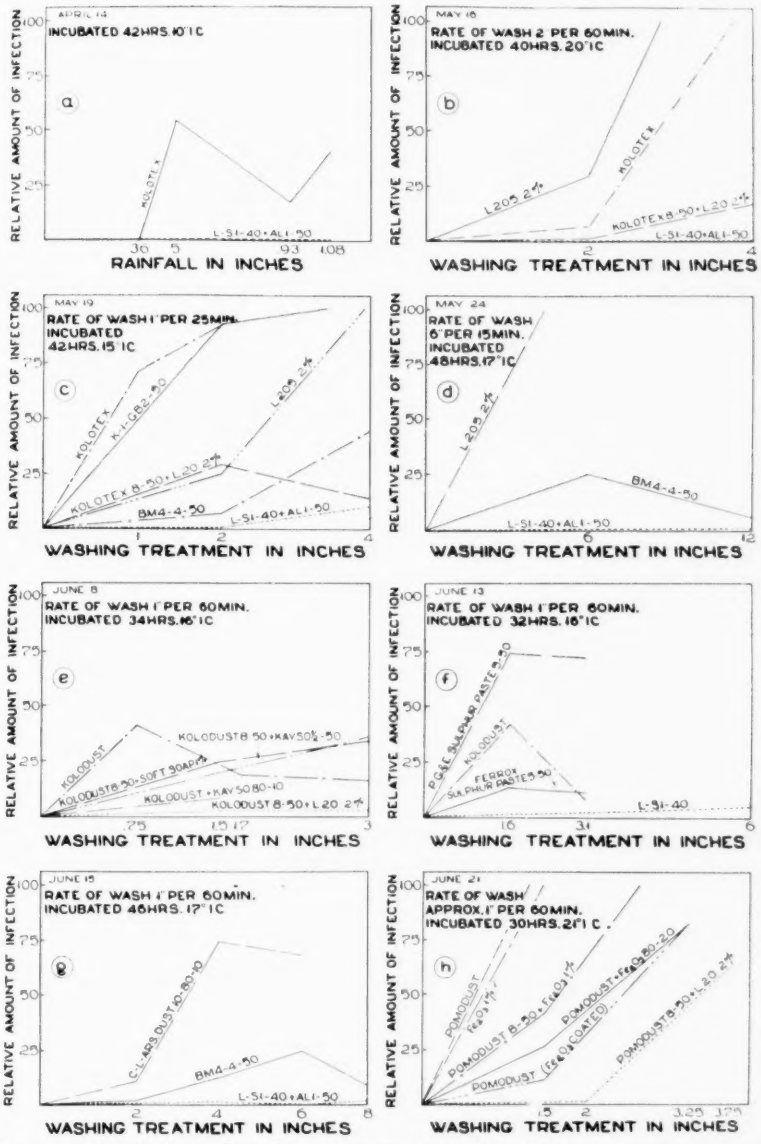

FIG. 5. The relation of washing treatments to the effectiveness of certain fungicides in preventing apple-leaf infection by the ascospores of *Venturia inaequalis*. L-S = Commercial liquid lime sulphur. AL = Commercial powdered arsenate of lead. L20 = Emulsified oil. L205 = L20 plus a form of sulphur. K-1-CB = Proprietary mercurial compound. BM = Bordeaux mixture. Kayso = Casein lime. Soft soap = Neutral sodium soft soap (20th Century Soap). C-L-Ars. = Copper-lime-lead arsenate. Pomodust (Fe_2O_3 coated) = Pomodust was suspended in a 2 per cent solution of ferric oxide, dried and resifted.

a The regular nozzles of the chambers were running full force.
b The washing was by natural rain.
c Pomodust was suspended in a 2 per cent solution of ferric oxide, dried and resifted.

washing, in which lake water was used, was somewhat similar to that of a fine, gentle rain. After treatment the trees were inoculated in the usual way with the ascospores of *Venturia inaequalis* and then incubated in the greenhouse for a suitable time. The method of taking results was similar to that in previous experiments.

Treatments and results. Thatcher and Streeter (51) found that, after the first major mechanical loss, rain was apparently a minor factor in affecting the adherence of sulphur dust to foliage. Their data show a great mechanical loss for the sulphur dust during the first week, and by the end of the second week the major part of the sulphur, even in heavy dustings, was removed. Subsequent decrease in the amount of sulphur was small and rather uniform during the ensuing weeks. In the use of lime-sulphur spray the proportion of sulphur washed off during the early period was much less than that for the dust, and the rate was more gradual, especially for the first three weeks.

It was reported by Young and Tisdale (63) that particulate sulphur stuck better than coarse particles and that a heavy downpour of rain washed off less sulphur than the same amount of water falling more slowly and over a longer period.

A summary of treatments and of results appears in table 8 and figure 5. Sulphur dust was much inferior in adhesiveness to sulphur deposited by sprays containing lime sulphur (Table 8, Ser. 1, 2, 3, 6, or Fig. 4, a, b, e, f). Apparently, after a light rain or a short washing period, the major part of the sulphur dust was washed off, for under these conditions considerable infection took place. In the case of sprays containing lime sulphur enough of the sulphur adhered to the foliage after the so-called first major mechanical loss to provide protection even after a heavy rain or prolonged washing treatments. Bordeaux mixture was slightly less effective than lime sulphur after prolonged washing (Table 8, Ser. 4, 7, or Fig. 5, d, g). Copper-lime-arsenate dust was decidedly less adhesive than Bordeaux (Table 8, Ser. 7, or Fig. 4, g). P. G. & E. sulphur paste and Ferrox sulphur paste, both finely divided wettable sulphur products, were much inferior to lime sulphur in their efficiency for scab control after washing treatments (Table 8, Ser. 6, or Fig. 4, f). A proprietary emulsified oil, L205, containing a fungicide, was not significantly more effective than sulphur dust (Table 8, Ser. 2, 3, 4, or Fig. 5, b, e, d). It appears that the toxic agent was washed out, since oil emulsion to which sulphur dust was added at the time of application was decidedly more effective, as will be shown later. Perhaps this was due to the greater amount of sulphur in the latter mixture. A proprietary mercury compound did not appear to withstand washing any better than Kolotex (Table 8, Ser. 3, or Fig. 5, e). Arsenate of lead did

not appreciably increase the effectiveness of sulphur dust under the conditions of these experiments.

Casein lime may increase to a small degree the durability of the sulphur dust when proportioned for use either as a spray or dust (Table 8, Ser. 5, or Fig. 5, e). Soft soap was no more satisfactory than Kayso in rendering the sulphur dust more effective (Table 8, Ser. 5, or Fig. 5, e). The oil emulsion, L20, was the most promising of the stickers or spreaders tested with the sulphur dusts under these conditions (Table 8, Ser. 2, 3, 5, 8, or Fig. 5, b, c, e, h). The results (Table 8, Ser. 8, or Fig. 5, h) are in accord with the findings of Ginsburg (14, 16). Increased adhesiveness was manifest whether ferric oxide was added directly to sulphur dust, which may be proportioned for use either as a spray or dust, or was used as a coating on the sulphur-dust particles.

Control trees which had not been given a special washing treatment just before inoculation offered marked inhibition to the fungus (Table 8, Ser. 2, 4, 6). These trees, along with all the other uninoculated trees, had been well washed with a spray of water at frequent intervals with the aim of keeping the foliage clean. The variation in durability of the same fungicides for different series is due, in part, to a difference in the height of the twigs of the trees, the position of the trees on the table, the angle of the nozzle, the rate of washing, and the type of foliage. It must be kept in mind that these data are fragmentary. However, it is thought that considerable value attaches to the comparison of the various treatments within a series and that the data, taken as a whole, are significant regarding certain aspects of the relative adhesiveness of the fungicides tested.

RELATION OF THE ADDITION OF POTASSIUM PERMANGANATE TO THE TOXICITY OF SULPHUR DUST

Young's theory that the fungicidal effect of sulphur is due to the formation of pentathionic acid by oxidation in the presence of oxygen and water led Lee and Martin (32) to think that the fungicidal effectiveness of sulphur might be increased by adding oxidizing agents. They made field experiments on the control of eyespot disease of sugar cane, from which they concluded that the addition of 1 per cent potassium permanganate to sulphur dust increased its efficiency 200 to 300 per cent. The present writer, upon conducting comparative tests of various brands of sulphur acting across space, failed to find that the presence of 1 per cent potassium permanganate in the sulphur increased the effectiveness of the sulphur to any great extent. This indication is congruent with the more recent work of Bailey and Greaney (1), who conducted an investigation in connection with the control of leaf and stem rust of wheat. Goodwin and Martin (24) give data to indicate the nonproduction of a volatile sulphur derivative of

TABLE 9.—*The relation of the addition of potassium permanganate to the toxicity of sulphur dust to the spores of Sclerotinia cinerea in van Tieghem cells*[a]

Fungicide	Position of fungicide	Incubator		Final results		
		Temp.	Period in	Germination	Length of germ tubes	
		°C.	Hrs.	Per cent	Microns	Rel. No.
Series 1						
Control		20	8	90.7	82.8	100
Super-sulfodust	Bottom of cell	20	8	97.2	78.9	95
Super-sulfodust + $KMnO_4$ 1%	"	20	8	93.3	66.8	81
Series 2[b]						
Control		28	10	100.0	123.0	100
Super-sulfodust	Bottom of cell	28	10	35.4	12.3	10
Super-sulfodust + $KMnO_4$ 1%	"	28	10	30.0	8.2	7
$KMnO_4$	"	28	10	30.0	123.0	100
Series 3						
Control		28	8	95.3	75.0	100
Super-sulfodust	Bottom of cell	28	8	73.3	29.9	40
Super-sulfodust + $KMnO_4$ 1%	"	28	8	86.0	30.7	41
Series 4[c]						
Control		20	8	98.0	81.2	100
Super-sulfodust 10^2	In spore drop	20	8	0.0	0.0	0
Super-sulfodust 10^3	"	20	8	65.6	22.6	28
Super-sulfodust 10^4	"	20	8	92.0	53.3	66
Super-sulfodust + $KMnO_4$ 1% 10^2	"	20	8	6.0	12.3	15
Super-sulfodust + $KMnO_4$ 1% 10^3	"	20	8	71.0	25.8	32
Super-sulfodust + $KMnO_4$ 1% 10^4	"	20	8	59.0	41.0	50
$KMnO_4$ 10^3	"	20	8	0.0	0.0	0
$KMnO_4$ 10^4	"	20	8	66.1	45.1	56
Series 5[b]						
Control		20	8	98.0	109.5	100
Oxidized sulphur	Bottom of cell	20	8	48.0	32.8	30
Ferrox sulphur dust	"	20	8	63.1	44.3	40
Super-sulfodust	"	20	8	51.0	22.9	21

[a] The technique is described under the section on laboratory studies.

[b] Excess of the fungicides was used in the bottom of each cell. Oxidized sulphur = Sublimed sulphur plus potassium permanganate and a catalyst.

[c] The concentration of fungicide is denoted by 10^2, 10^3, 10^4. Growth developed later in the spore drops containing $KMnO_4$.

acid reaction from the use of potassium permanganate with sulphur in the presence of heat and moisture. Williams and Young (58) reported that sulphur, treated with certain oxidizing agents, such as potassium permanganate, was extremely toxic and was effective in the control of apple scab. Martin (35) obtained data which further substantiate the results of Lee and Martin (32).

Laboratory studies. The use of potassium permanganate with sulphur was studied in the laboratory, employing the technique described in a later section. The data obtained are presented in table 9, and figure 6, a, b. Percentage germination and reduction in length of germ tube of the conidia of *Sclerotinia cinerea* were used as criteria of toxicity. Certain tests were conducted across space in van Tieghem cells at 20° to 28° C. (Table 9, Ser. 1, 2, 3, 5, and Fig. 6, b). The fungicides were placed at the bottom of the cell, and the spores, in the hanging drop. The data do not suggest any significant increase in the effectiveness of Super-sulfodust or sublimed sulphur through the addition of potassium permanganate under these conditions. The trend of the results does not appear to be altered materially by a rise in temperature from 20° to 28° C. or by the amount of mixture used. Potassium permanganate in itself was not active across space. Combinations similar to the above were tested in the hanging drop itself at 20° C. (Table 9, Ser. 4, Fig. 6, a). The data corroborate the above results. Potassium permanganate was found to be more effective than sulphur when used alone in the hanging drop at the same concentration as with the sulphur (Table 9, Ser. 4).

Greenhouse studies. When oxidized and sublimed sulphur were compared in treatments made after infection periods of from 45 to 65 hours (Table 2, Ser. 1, 2, 4), there was no evidence that the oxidized sulphur was substantially more effective than sublimed sulphur. A comparison of oxidized sulphur with other types of dusts and sprays applied after infection periods of from 48 to 64 hours did not reveal any unusual effectiveness of the oxidized product (Table 2, Ser. 5, 37). Temperature within the range of 10° to 23° C. and a moist treatment after application appeared to play a rather insignificant rôle in increasing the amount of control with the activated sulphur. Potassium permanganate, 2 per cent, gave excellent control as compared with the other treatments listed, when applications were made 45 to 66 hours after inoculation began (Table 2, Ser. 1, 4).

SOME OBSERVATIONS ON THE EFFECTIVENESS OF FUNGICIDES

In analyzing the data relative to the control of *Venturia inaequalis* by means of various fungicidal treatments one must consider certain related factors, some of which have not been mentioned. It is quite possible that

† The concentration of fungicide is denoted by 10^{-2}, 10^{-3}, 10^{-4}. Growth developed later in the spore drops containing $KMnO_4$.

there is a variation in the degree to which the ascospores of *V. inaequalis* can withstand the action of toxic materials. This may possibly be influenced by such factors as the "strains" of fungus used, the time of the year at which the spores matured, the vigor of individual spores, and the abundance of inoculum. The length of time after inoculation that control may be obtained is undoubtedly somewhat variable due to the time required for the leaves to collect sufficient moisture[9] for germination, and other factors. It is quite obvious that the trees vary in resistance at different times. Usually the three or four leaves most recently unfolded are susceptible to infection on the ventral surface, but, occasionally, trees will be found on which practically all the foliage is susceptible. Frequently it is found, especially where a fungicide was not applied, that the fungus in lesions on the more susceptible leaves at the top of the twigs breaks through the cuticle and sporulates, whereas, farther down the twigs the leaves are more mature and sufficiently resistant to prevent macroscopic development of lesions.

The trees grown in the greenhouse showed evidence of considerable variation in the carbohydrate-nitrogen ratio as conditions changed during the course of the season. The nitrogen-high condition seemed to increase the susceptibility to scab infection and to lime-sulphur injury. The nitrogen-high condition which commonly developed in the plants first forced (February and March) was corrected by providing artificial light.

In the case of post-inoculation treatments, especially in the use of the more effective sprays such as lime sulphur, it was found that the development of macroscopic lesions was delayed for days and the fungus in them might never fruit. Although this may not have any effect on the development of the perfect stage of the fungus, it checks the development of the conidial inoculum and in this way is a factor in fungicidal effectiveness which is not fully apparent from the data.

As a result of the rapid growth of apple trees in a shaded greenhouse, the texture of the leaves is somewhat different from that of the leaves of trees grown in an unshaded greenhouse. The trees used in these experiments were shaded for the most part during the periods of excessive heat so that infection would take place and lesions would appear.

LABORATORY STUDIES: APPARATUS AND METHODS

The conidia and ascospores of *Venturia inaequalis* and the conidia of *Sclerotinia cinerea* were used in laboratory studies. The conidia of *V.*

[9] The amount of particulate water that passed through the cloth top of tenting material over the iron frame in the moist chamber varied somewhat in the earlier work. This variation was eliminated on March 12, 1929, and, thereafter, by spraying the top from within just before the experiment began. This procedure filled the small apertures in the fabric with water, prevented the passage of droplets, and insured a saturated atmosphere without the danger of excess water.

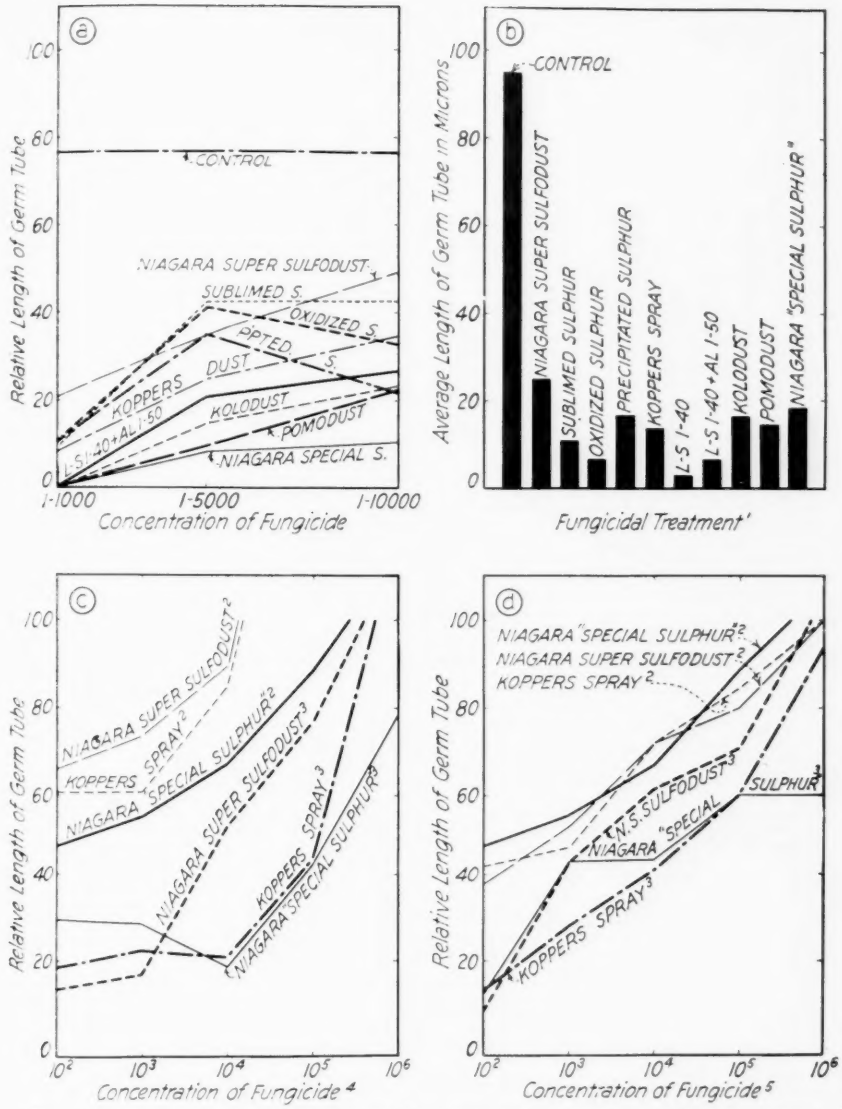

FIG. 6. The toxicity of certain sulphur fungicides to the conidia of *Sclerotinia cinerea* as determined by inhibition in length of germ tube in van Tieghem cells. Relative length of germ tube is based on the control which is taken as 100. Oxidized S = Sublimed sulphur plus potassium permanganate, 1 per cent, and a catalyst. P'pted S = Prepared by aerating lime sulphur. Koppers dust = Prepared from Ferrox flotation sulphur paste. L-S = Commercial liquid lime sulphur. AL = Commercial powdered arsenate of lead. Niagara "special sulphur" = Bentonite sulphur. Koppers spray = Prepared from Ferrox flotation sulphur paste. a. Fungicide and conidia in hanging drop, 20° C. b, c, d. Fungicide in bottom of cell, 28°, 17°, and 17° C., respectively. 1. A 2 per cent suspension of the fungicide was used. Aliquots of the suspension to be tested were dried down and slightly moistened just before the experiment was begun. 2. Conidia of *Sclerotinia cinerea*. 3. Conidia of *Venturia inaequalis*. 4. Sulphur dry. (Aliquots of the suspension to be tested were dried down.) 5. Sulphur wet. (Aliquots of the suspension to be tested were not dried down.)

inaequalis were washed from apple leaves from the orchard by means of an atomizer. In order to secure a clean leaf surface and a fresh crop of spores, the leaves were washed with sterile distilled water 3 or 4 days before they were collected, and covered with parchment bags. The ascospores of *V. inaequalis* were ejected from perithecia in moistened apple leaves into sterile conductivity water. *Sclerotinia cinerea* was cultured on potato-dextrose agar at 20° C. and the spores were taken from 7- to 9-day-old cultures.

The hanging-drop technique was used. Conductivity water was used for spore suspensions and the preparation of fungicides. The glassware was cleaned with potassium bichromate and sulphuric acid cleaning solution, thoroughly rinsed in ordinary distilled water, then in sterile conductivity water, and finally wiped with clean cheesecloth. All cover slips and slides were flamed just before using. The rings were 10 x 18 mm. The cells, unless otherwise stated, were left unsealed with a small opening at the edge of the cover slip to allow free access of oxygen. Four cells were used for each dilution. The drops of the spore suspension to be used as an indicator of the toxicity of the fungicide were taken with a platinum loop 2.5 mm. in diameter by a standardized procedure. The drops contained about 15 spores per low-power field of the microscope, or approximately 100 to 200 spores per drop.

The dilutions of the fungicide were based on the dry weight of the sulphur or sulphur mixture, except that, in the case of sprays containing lime sulphur, the dilution 1–40 was used as a basis. Aliquots of the various dilutions to be tested across space were transferred by means of a platinum loop 6.5 mm. in diameter. One loopful of a 1 per cent suspension of the sulphur preparation to be tested was placed in the bottom of each cell, unless otherwise stated. These drops were allowed to evaporate slowly until air-dry and then slightly moistened before the cover slip bearing the spores in a drop of sterile conductivity water was suspended over them. When the fungicidal dilutions were tested in the spore suspension, its evaporation was prevented by placing a large loop of water in the bottom of the cell. Water was used instead of the same fungicide that was in the hanging drop to avoid the complication of having any fungicide at the bottom of the cell where it might act across space on the spores at the bottom of the hanging drop. The cells were then incubated in sterile Petri dishes freshly lined with moist filter paper. Readings of germ-tube length and percentage of spores germinated were made at suitable times. The results of this work showed that the percentage of spores germinated was not a satisfactory criterion of the toxicity of the materials tested. Ordinarily 100 germ tubes were measured for each dilution. At the end of the incubation period the spore drops were allowed to evaporate to dryness and the cover

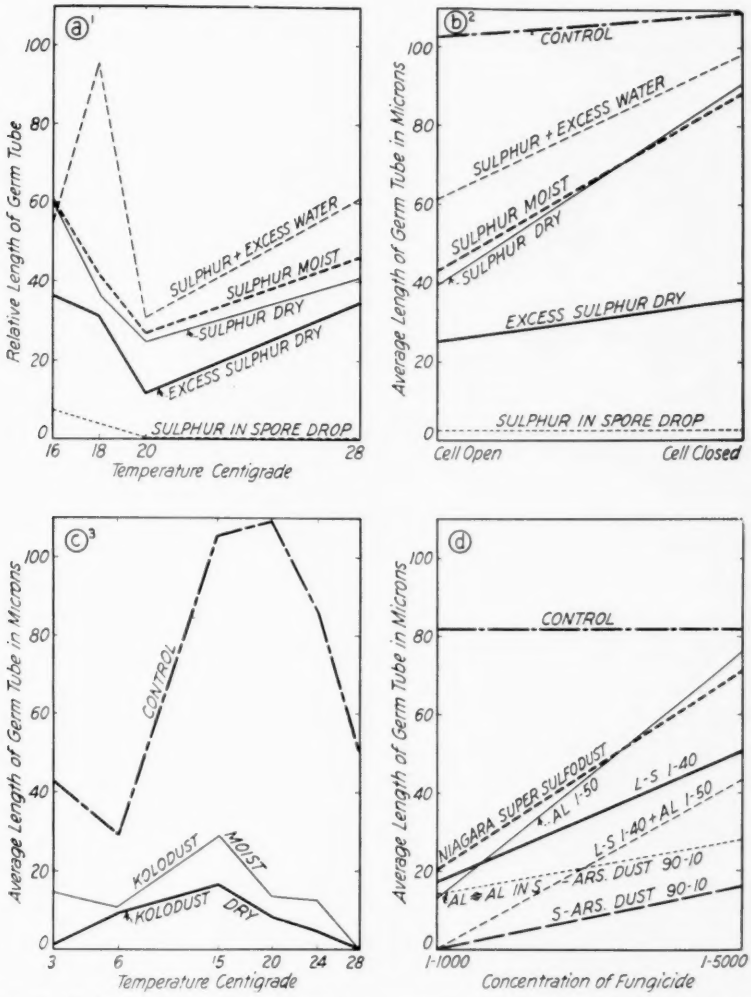

FIG. 7. Relation of water, temperature, oxygen, and arsenate of lead to the toxicity of certain fungicides as determined by inhibition in length of germ tube in van Tieghem cells. Relative length of germ tube is based on the control which is taken as 100. a, b. Conidia of *Sclerotinia cinerea*. Fungicide in bottom of cell. c. Ascospores of *Venturia inaequalis*. Fungicide in bottom of cell. d. Fungicide and conidia of *Sclerotinia* cinerea in hanging drop, 20° C. 1. Sulphur = Niagara Super-sulfodust. Sulphur + excess water = Aliquots of the suspension to be tested were not dried down. Sulphur moist = Aliquots of the suspension to be tested were dried down and slightly moistened just before experiment was begun. Each temperature is average of 2 series. 2. Sulphur = Niagara Super-sulfodust. The data are based on the average of 8 series, 2, each, for the temperatures 16°, 18°, 20° and 28° C. The degree of inhibition in the effectiveness of the sulphur due to the closed cell was not significantly different at any one of these temperatures. 3. A 2 per cent suspension of the dust was used.

slips dipped in formal-acetic-alcohol and stored in water until readings could be made. Any deviation from the technique as described in this section is noted in each particular instance.

No readings were taken from those spore drops that were clearly abnormal, as in the following cases. Under certain conditions germ tubes grew up into the drop away from the lower surface, thus escaping full exposure to the toxic agent; spores germinated and grew more readily in clumps than when evenly dispersed throughout the drop; irregularity in the size of drop due to the effect of surface tension between the drop and the glass surface sometimes caused variation with regard to the distribution of the spores; if the cells were not level, the spores would collect on the edge of the drop, thereby producing an abnormal oxygen relationship; and considerable variation in the number of spores per drop occasioned a variance in the effectiveness of the material used.

The technique used for making the sulphur suspensions was standardized as far as possible.

A COMPARISON OF THE TOXICITY OF CERTAIN SULPHUR FUNGICIDES AT VARIOUS CONCENTRATIONS IN THE SPORE DROP

That the fineness of the sulphur particle is a fungicidal determinant has been reported by various workers since the early investigation of fungicides, as reviewed by Windisch (60). This property of sulphur, which is considered important in relation to its adhesiveness and toxicity, has recently received considerable attention by Young (61) and Tisdale (52). Goodwin, Martin, and Salmon (20) found that colloidal sulphur was apparently decidedly more effective than wetted ground sulphur as a spray with soft soap against the hop "powdery mildew" (*Sphaerotheca humuli*).

The data (Fig. 5, a) show on a comparative basis the relative toxicity of various sulphur dusts when tested in the hanging drop, using the conidia of *Sclerotinia cinerea* as a criterion of toxicity at 20° C. It appears that any significant difference in the effectiveness of the several materials tended to disappear as the concentration in the spore drop increased below 1–1000.

Across space

The fact that sulphur acts across space is reported by authorities already cited (Barker, Gimingham, and Wiltshire (2), Young (61), Barker (3, 4), Goodwin and Martin (24), Marsh (34)). Figure 6, b, c, d, and figure 7, a, b, c, show the effectiveness of sulphur fungicides across space in van Tieghem cells. Figure 6, b, c, d, is representative of the comparative data obtained relative to several sulphur fungicides, the toxicity being measured by the inhibition in length of germ tube of the conidia of *Sclerotina cinerea* and *Venturia inaequalis* at 17° and 28° C. It is apparent that there was no

significant difference in any of the sulphur materials tested under these conditions, although it would appear from figure 6, c, d, that Niagara Super-sulfodust was less effective than the more finely divided Niagara "special sulphur" (Bentonite sulphur), except, perhaps, in the presence of water. The materials tested include Niagara Super-sulfodust, Pomodust, Kolodust, Niagara "special sulphur" (Bentonite sulphur), Koppers spray (Ferrox sulphur paste), precipitated sulphur (prepared by aerating lime sulphur), sublimed sulphur, oxidized sulphur, lime sulphur, and lime sulphur plus arsenate of lead.

THE EFFECT OF TEMPERATURE AND WATER ON THE TOXICITY OF CERTAIN SULPHUR FUNGICIDES

Studies made in the laboratory on the effect of temperature and humidity or water on the amount of control obtained with some sulphur fungicides by Doran (10), Young (61), Tisdale (52), and Goodwin and Martin (24, 25) have been reviewed earlier.

Tests of the effect of temperature on the fungicidal action of sulphur across space were conducted in van Tieghem cells in which the sulphur (Super-sulfodust) was placed at the bottom of the cell and a conidial suspension of *Sclerotinia cinerea* or an ascosporic suspension of *Venturia inaequalis* was placed above as a criterion of toxicity. The greatest inhibitory action of sulphur across space against the conidia of *S. cinerea* and the ascospores of *V. inaequalis* seemed to be about 20° C. under these conditions (Fig. 7, a, c). An interpretation of these results should take into account the effect of temperature on the germinating spore, as well as on the toxicity of the sulphur. Sulphur apparently was toxic to the ascospores of *V. inaequalis* when tested across space at 3° C. (Fig. 7, c).

Water may decrease the inhibitory action of sulphur across space, and this effect does not appear to be influenced more at one degree of temperature than at another within the range of 3° to 28° C. (Fig. 6, c, d, and Fig. 7, a, b, c). Droplets of lime sulphur 1–40, air dried at the bottom of the cell and then covered with a drop of water, showed no toxic effect across space on the conidia of *Sclerotinia cinerea.*

The data (Fig. 7, b) show that there was a distinct decrease in the amount of inhibition obtained with sulphur when tested across space on the conidia of *Sclerotinia cinerea* in sealed cells, as compared with that obtained in open cells. This effect was not so marked in cells in which sulphur was used in excess in the bottom of cell or in the spore drop. Young (61) reported that there was not sufficient oxygen in sealed cells to permit optimum effectiveness of sulphur. Goodwin and Martin (24) state that oxygen does not appear to be of importance in the production of the "volatile sulphur derivative" from sulphur which produces a stain on copper foil.

THE FUNGICIDAL ACTION OF ARSENATE OF LEAD

Laboratory tests which have been adequately reviewed by Butler and Doran (18) indicate that arsenate of lead is not lethal to *Venturia inaequalis* at the strength used in orchard spraying but that it increases the toxicity of lime sulphur.

Arsenate of lead was found markedly to increase the toxicity of Supersulfodust and lime sulphur against the conidia of *Sclerotinia cinerea* in the hanging drop at 20° and 17° C., respectively, and to have fungicidal properties of its own (Fig. 6, a, and Fig. 7, d). Other data indicate that soluble arsenic is fungicidal and apparently inhibitory in its action. Inhibition is evident over a wide range of dilutons.

SUMMARY

1. This study of the control of apple scab with fungicides has consisted chiefly of greenhouse experiments in which the fungicides could be applied at will to trees on which the disease was induced by inoculation under partly controlled conditions. Attention has been directed as far as possible toward a simulation of natural conditions. Special attention has been given to a study of the comparative efficiency of various sulphur fungicides and to the relation of certain factors of the environment to their effectiveness.

2. All fungicides applied before inoculation gave excellent control if the trees were not subjected to washing. These included a series of sulphur dusts, sprays containing lime sulphur, Bordeaux mixture, and certain emulsified oils. Leaves treated with sulphur dust or lime sulphur spray were efficiently protected until they became resistant. Bordeaux mixture was somewhat less effective. The fungicidal effectiveness of sulphur dusts and lime sulphur was not appreciably changed when applied to the foliage and given a period in the moist chamber before inoculation. Temperature within the range of 6° to 23° C. during an infection period appeared to be more important in its relationship to the development of host and parasite than to the toxicity of sulphur. Excellent control was obtained at 6° C.

3. The fungicides showed differences in effectiveness when applied after inoculation. Sprays containing lime sulphur appeared to be distinctly more effective than the sulphur dusts (whether finely ground, sublimed, "activated," or containing arsenate of lead), wettable sulphur sprays, calcium monosulphide, Bordeaux mixture, emulsified oils with or without a sulphur fungicide, and certain proprietary mercury compounds. Sulphur-arsenate dust 90–10 suggested little indication of offering control in certain tests when applied later than about 12 hours after inoculation, unless the application was followed by a moist treatment, while sprays containing lime sulphur, especially lime sulphur 1–40 plus arsenate of lead 1–50, gave

good control when the application was made after infection periods ranging from 30 to 72 hours, and in some cases longer. Under the conditions of these experiments the data do not seem to indicate any significant difference in scab control between the various wettable sulphur pastes or finely ground sulphur preparations and the less finely divided sulphur products tested, which is attributable to their various physical states. Bordeaux mixture gave consistent control and was more effective than certain sulphur dusts or finely divided sulphur sprays. Certain emulsified oil treatments and proprietary mercury compounds appeared to exhibit marked effectiveness. The quantity of ascosporic inoculum was a factor in the effectiveness of sulphur fungicides applied after inoculation. Fungicidal applications made after infection show that temperatures ranging from 6° to 23° C. during an infection period did not materially affect the control of *Venturia inaequalis*, while temperatures above 26° C. became an appreciable factor in the inhibition of the fungus. The degree to which temperature was a factor was determined by the length of time that elapsed after inoculation before exposure to the higher temperature, the length of exposure to that temperature, the temperature itself, and probably the relative humidity. It is apparent that the higher temperatures were most effective against the organism before penetration had taken place. Data have been obtained which show that moisture was an important factor in the maximum effectiveness of many fungicides, such as sprays containing lime sulphur, when applied after an infection period, in the control of *V. inaequalis*. Histological evidence shows that *V. inaequalis* may be effectively controlled after infection has taken place.

4. There is indication that lime sulphur was quickly effective when applied at the time of inoculation or shortly after but that it required considerable length of time to be effective if the treatment was made some time after inoculation.

5. Rapid drying of lime sulphur appeared to increase its effectiveness in applications made after inoculation.

6. Lime 3–50 was not found to diminish the action of lime sulphur plus arsenate of lead to any appreciable extent when applied after infection periods.

7. The effectiveness of sulphur-lead arsenate dusts or sprays applied after infection periods appeared to be increased if a moist treatment was given for a period following the application. There is evidence that the increased effectiveness of lime sulphur from the addition of arsenate of lead is due, at least in part, to soluble arsenic. Soluble arsenic, As_2O_5, may be fungicidal alone. Injury did not result, under the conditions of these experiments, when soluble arsenic, As_2O_5, was applied alone at the

concentration of 0.04 per cent or with lime sulphur 1–40 at the concentration of 0.03 per cent.

8. Kayso (casein lime) sulphur appeared to increase the fungicidal property of lime sulphur plus arsenate of lead when applied after infection but the effect was not striking. Lime sulphur plus Kayso plus arsenate of lead seemed to be the most effective combination tried.

9. The effectiveness of certain sulphur fungicides was found to be increased when applied in a soft-soap solution.

10. Oil emulsion applied before or after inoculation seemed to exhibit fungicidal properties. The addition of oil emulsion appeared markedly to increase the effectiveness of some fungicides.

11. The proprietary mercurial compounds tested may be decidedly effective, under certain conditions, when applied after infection.

12. Development of conidia of *Venturia inaequalis* on leaf lesions was checked according to the fungicidal effectiveness and adhesiveness of the materials used.

13. Certain sulphur fungicides and Bordeaux mixture exhibited effectiveness over a larger area than the actual surface covered.

14. No significant increase in fungicidal efficiency of sulphur followed the addition of potassium permanganate to sulphur as an oxidizing agent.

15. The sprays containing lime sulphur and Bordeaux mixture are apparently decidedly more adhesive than certain sulphur dusts, finely divided sulphur sprays, emulsified oils, and other fungicides tested. Sulphur dust was ineffective after a short period of rain or washing treatment, while the lime-sulphur-containing spray was protective after a heavy rain or prolonged washing treatment.

16. The addition of such spreaders or adhesives as soft soap, emulsified oil, Kayso (casein lime), and ferric oxide increased the adhesivenes of certain fungicides to a greater or lesser extent. Emulsified oil gave the most satisfactory results.

17. Laboratory studies corroborated the greenhouse studies of sulphur fungicides as regards the inhibitory action of sulphur, the action of sulphur other than by contact, the effectiveness of potassium permanganate as a fungicide and its ineffectiveness as an "oxidizer" for sulphur dust, the fungicidal effectiveness of precipitated (aerated) lime sulphur, certain temperature relationships, and the fungicidal rôle of arsenate of lead and soluble arsenic.

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RELATIVE SUSCEPTIBILITY OF VARIETIES OF SORGHUM TO RUST, PUCCINIA PURPUREA[1]

C. O. Johnston and E. B. Mains

INTRODUCTION

The many varieties of sorghum which are grown in the United States as grain, forage, or sirup crops, under many different environmental conditions, are known to be attacked by several fungous and bacterial diseases. In the literature on diseases of sorghums, references to rust caused by *Puccinia purpurea* Cke. are very limited and little is known concerning the occurrence of that disease in North America. It, therefore, was interesting to note outbreaks of rust on sorghums at Manhattan, Kansas, and near La Fayette, Indiana, in 1927. At Manhattan natural epiphytoties of rust developed in varietal sowings in the field in 1927, 1928, and 1929, while infections were artificially induced in varietal sowings at La Fayette in 1928 and 1929. Therefore, it was possible to make comparative rust readings on varieties at both stations and to note differences in susceptibility. The data secured at La Fayette in 1927 already have been briefly presented by Mains (5). The detailed results of experiments at both stations are presented in this paper.

DISTRIBUTION OF THE DISEASE

Sorghum rust usually has been considered a disease of southern distribution and seldom has been reported as far north as Kansas and Indiana. It has frequently been reported from Louisiana and Texas and occasionally from Oklahoma, but usually only from the more humid sections of those States. It is of interest to note that rust is seldom seen in the heavy sorghum-producing sections of northwestern Texas and Oklahoma and southwestern Kansas. Although the temperature undoubtedly is favorable for the rust in that area, it is much too dry for its satisfactory development over most of the area in a normal season. The senior writer noted a small amount of rust on sorghum varieties at the Woodward, Oklahoma, field station in 1927, but that was an unusually wet season in northwestern Oklahoma.

The rust is rather widely distributed throughout the warm temperate and tropical portions of the world. The Sydows (7, pp. 803–805) list *Puc-*

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cinia purpurea from Italy, Greece, Portugal, India, Java, and North America. Arthur (1) also lists it from South America. In North America, Arthur and Fromme (3, pp. 284–285) list it from Alabama, California, Florida, Louisiana, South Carolina, Texas, Guerrero, Vera Cruz, Yucatan; Cuba; Jamaica; Costa Rico; Bermuda; Porto Rico.

CHARACTERISTICS OF THE FUNGUS

Puccinia purpurea probably is heteroecious but its aecial host is unknown. Uredinia are produced, usually in purplish spots, on both sides of the leaf. They are rather small and somewhat tardily naked. The urediniospores are cinnamon or dark chestnut brown, 23–31 by 29–40 μ, finely and rather closely echinulate, with 5–10 germ pores that either are scattered or variously arranged in two transverse bands. The uredinia contain conspicuous clavate or capitate paraphyses, figure 1, which usually

FIG. 1. Section through uredinium from feterita showing paraphyses characteristic of *Puccinia purpurea*.

have a brownish purple wall and are generally more numerous at the margin of the uredinium. The compact and dark chocolate brown telia are somewhat larger than the uredinia. The teliospores are ellipsoid or oblong, 23–32 by 40–50 μ.

Arthur and Fromme (3) list *Holcus halapensis* L. (Johnson grass), *H. sorghum* L. (sorgo) and *H. sorghum sudanensis* (Piper) Hitchc. (Sudan grass) as hosts for this rust. According to the Sydows (7), Barclay described a rust from *Pennisetum typhoideum*, which, from Barclay's de-

scription, is identical with *Puccinia purpurea*. Butler (4, pp. 206–208), however, questions the identity of the host and rust. The Sydows (7) also list *Zea mays* as a host from Natal, Africa. This also would appear somewhat questionable since *P. purpurea* has never been reported on maize elsewhere. The rust of maize, *P. sorghi* Schw., may produce intense purplish spots under certain conditions on maize carrying anthocyanine factors. *Puccinia purpurea*, however, is easily distinguished from *P. sorghi* by its characteristic paraphyses.

In this connection it is interesting to note that the rust of maize was described by Schweinitz (6, pp. 141–316) in 1834 from material that he apparently assumed was sorghum (2). He consequently gave it the name *Puccinia sorghi*. The rust of maize never has been found on sorghum. Although the name was applied evidently through a mistake in identification of the host, a strict adherence to the rules of nomenclature has resulted in a perpetuation of this misnomer and necessitates the application of another name to the rust of the sorghums.

SORGHUM RUST IN THE SOUTHERN GREAT PLAINS

The first occurrence of rust on sorghums in Kansas was recorded at Manhattan on August 20, 1927, when a rather heavy infection was noted on the lower leaves of sorghum varieties in experimental sowings. A more severe outbreak occurred in the same plots in 1928 and this was followed by a much lighter infection in 1929. Weather conditions favored the development of sorghum rust in the southern great plains in 1927 and 1928, both seasons being marked by heavy rains in late summer.

The disease developed very late in each of the three seasons at Manhattan; the dates of first appearance being August 20, 1927, August 13, 1928, and August 26, 1929. The first signs of infection appeared as scattered uredinia on leaves near the ground. During the remainder of the season the rust developed slowly but with such severity that the lower leaves of susceptible varieties were completely killed and the upper leaves also were severely affected. In all cases rust continued to develop until the host plants were killed by frost, the rate of development depending upon environmental conditions and the susceptibility of the sorghum variety.

The amount of injury caused by rust on sorghums is problematical. At Manhattan even those varieties most severely rusted yielded an abundance of seed of good quality in each of the three years. The belated development of rust and the ability of most sorghums to continue producing new leaf tissues through tillering and branching practically preclude the possibility of losses such as those resulting from rust in small grains. On the other hand, when most of the leaves are prematurely killed by rust,

as occurred in certain feteritas, Red Amber × feterita hybrids, and Manchu Brown kaoliang in 1927 and 1928, there can be no doubt that considerable reduction in yield results.

Rust readings were made on a total of 121 sorghum selections grown at Manhattan, Kansas, during 1927, 1928, and 1929. These consisted of inbred lines of varieties, hybrids, and selections then being used in studies on the physiologic forms of covered kernel smut. Not all of the 121 selections, however, were grown each of the three years; 42 of them had been grown only one year and 17, two years. The remaining 62 selections were grown in all three years. In most cases the selections had been inbred for several years, but a few varieties had been inbred only a year or two. Particular care was exercised in the inbreeding operations to select plants having characteristics typical of the named variety. During the growing seasons any obviously off-type plants were promptly removed from the plots. Thus a set of selections of very uniform type was available for study. In some of the hybrid lines it was very difficult to select strains that would react the same from year to year. This apparently was because of the fact that they were still heterozygous for certain characters, although homozygous for gross morphologic characters. In general, however, the rust readings indicated that the selections were uniform for their reaction to rust.

The varieties were grown in 50-foot rows with plants spaced about 4 inches apart. Many plants of each variety therefore were available for examination. Since the varieties were sown each year in triplicate it was possible to make several readings on each variety. In 1927 all three series were examined and a single note recorded, giving the maximum and minimum percentage noted for the variety. In 1928 and 1929 notes were taken on each variety in each of the three series. From these data the range (minimum to maximum percentage) for each variety was calculated. Thus, the data presented in table 1 give the extremes noted for each variety each year.

The rust percentages noted for some of the varieties are very consistent for all of the years, while in other cases the results differed widely from year to year. It must be remembered that 1929 was a rather unfavorable year for the development of sorghum rust and that only the most susceptible selections had high rust readings. Moderately susceptible varieties had very low readings, frequently only a trace of rust being noted on them. The readings for 1927 were taken a little too early and therefore probably are a little lower than they should be. The readings of 1928 are undoubtedly the most accurate and therefore the best measure of resistance or susceptibility of a variety.

In presenting the data in table 1 the varieties, hybrids, and selections have been arranged into large groups such as kafir, sorgo, feterita, milo, etc. Thus, all closely related varieties are conveniently placed for comparison. The kafirs, as a rule, are only moderately susceptible to rust, the lower leaves frequently showing 20 to 40 per cent, while the upper leaves seldom show more than a trace. The data seem to indicate that Pink kafir is slightly more susceptible than Blackhull and that Club kafir probably is the most susceptible variety of the group. The latter probably is not a pure kafir, but a hybrid between kafir and feterita.

The sorgos differ considerably in their reaction to rust, some being rather susceptible, while others apparently are resistant. Red Amber, Freed, Kansas Orange, Leoti Red, and Dwarf Freed seem moderately susceptible, while Pink Freed and Honey sorgo are more resistant. The light infection of 1929 makes certain varieties seem less susceptible than they actually are. If all three years are considered, Dwarf Freed and Freed were the most susceptible of the sorgos, while Pink Freed was the most resistant. The difference in reaction of the two strains of Freed, Pink Freed, and Dwarf Freed, is very interesting. The former is a supposed natural cross between Freed and Pink kafir, while the latter is a dwarf selection from Freed made by A. F. Swanson at Hays, Kansas. The proper classification of Pink Freed is uncertain, since it is not a typical sorgo and cannot be placed in any of the other known groups.

The feteritas as a group were very susceptible to rust and, with few exceptions, the data in table 1 show this very clearly. The only evidences of resistance in this group were shown by a recent introduction, S. P. I. No. 51991, in 1927, and one of the strains of Red Leaf feterita, in 1929. The latter is a selection from normal feterita made by J. H. Parker. The entire plant turns a purplish red late in the season and is characteristically lacking in vigor. In 1929 this strain became red before rust infection occurred and very little rust developed thereafter. Another strain of Red Leaf feterita is much more vigorous and, although originally characterized by red leaves, it developed very little of the color in 1928 and 1929. It was scarcely distinguishable from normal feterita and shows the susceptibility characteristic of the variety.

Not only are the feteritas very susceptible to rust, but many of the hybrids having feterita as one parent also are very susceptible. Most of the Red Amber × feterita hybrids tested were very susceptible, although one of them seemed highly resistant in 1929. These selections were then in the F_3 generation. They are tall, juicy-stalk, white-seed segregates, combinations of forage and grain type. The kafir × feterita hybrids and milo × feterita hybrids also were moderately susceptible, although one selection of the latter had very little rust in 1929.

TABLE 1.—*Reaction of varieties of sorghum to Puccinia purpurea in three seasons at Manhattan, Kansas*

Variety	Serial[a] number	Range in rust percentage		
		1927	1928	1929
Kafir				
Reed	KB 2502	tr.–5	tr.–20	tr.–tr.+
Pink	KB 2506	10	tr.–40	tr.–5
"	KB 2546	40	tr.–40	10
Juicy Pink	FCI 9091	.....	tr.–20	10
Early Pink	KB 2824	.....	tr.–40	tr.+
Wonder	KB 2520	40	.....	.....
"	KB 2548	20	.....	.....
Sunrise	KB 2523	5–30	5–60	tr.
Blackhull	KB 2535	tr.–10	tr.–40	tr.
"	KB 2539	40	.....	.....
Dawn	KB 2538	tr.–10	tr.–20	tr.
"	HC 2421	20	tr.–40	5
Red	KB 2545	tr.–5	tr.–40	5–10
Farmer	KB 2554	30	.....	.....
Western Blackhull	HC 1462	5–20	tr.–40	tr.+
Bishop	KB 27103	tr.–2	.....	.....
Pearl	KB 27104	tr.–10	.....	.....
Rice	KB 27105	20	.....	.....
Sharon	KB 27106	40	.....	.....
Club	HC 281	.....	tr.–40	10–25
Sorgo				
Red Amber	KB 2504	30	20–60	tr.+
Freed	KB 2519	tr.	40–80	10
White African	KB 2521	30	.....	.....
Dwarf Sumac	KB 2576	40	10–40	tr.–
Sumac	KB 2902	.....	.....	tr.–
Kansas Orange	KB 2560	40	20–60	tr.–
"	KB 2572	40	.....	.....
Lasley	KB 2571	5	.....	.....
Leoti Red	FCI 6610	40	20–60	0–tr.–
Pink Freed	KB 2798	tr.–2	0–5	0–tr.–
Modoc Pink Freed	HC 2520	.....	tr.–40	10
Honey	KB 2874	30	tr.–20	0–tr.–
Dwarf Freed	KB 27107	30	40–60	20–40
"Japanese Honey Drip"	KB 2876	.....	tr.–40	5
Atlas Sel. 95	KB 2877	.....	tr.–40	5
" 100	KB 2878	.....	tr.–40	5
Feterita				
Spur	KB 2540	tr.–10	50–80	40
Red Leaf	KB 2543	tr.–20	50–80	tr.–5
"	KB 2544	tr.–20	60–80	25–40
Standard Feterita	CI 182–1	50	40–70	40
"	KB 2563	25	60–80	40–60
Standard Feterita Sel.	SPI 51989	30	50–80	25–40

TABLE 1.—*(Continued)*

Variety	Serial number	Range in rust percentage		
		1927	1928	1929
" "	SPI 51989	5–60	.....	.....
" "	SPI 51991	tr.–2	.....	.....
" "	SPI 51991	40	.....	.....
Hybrid Dwarf No. 6	KB 2820	.....	60–90	40–60
Milo				
Dwarf Yellow	KB 2511	5	tr.–5	0–tr.
"	KB 2512	tr.–2	.....	.....
"	KB 2514	tr.–10	.....	.....
"	KB 2515	tr.–5	0–tr.	.....
"	KB 2516	tr.–2	.....	.....
"	KB 2517	tr.–2	.....	.....
"	KB 2532	tr.	.....	.....
"	KB 2534	tr.–2	.....	.....
"	CI 332	tr.–10	0–tr.	0–tr.–
"	KB 2556	tr.–20	.....	.....
"	KB 2557	tr.–20	.....	.....
"	KB 2564	tr.–20	.....	.....
Standard Yellow	CI 234	5	0–tr.	0–tr.–
" White	CI 352	tr.–5	0–tr.	0–tr.–
Dwarf White	FCI 8927	5	0–tr.	0–tr.–
Cream	KB 2569	5	0–tr.	0–tr.–
Dwarf Straightneck[b]	KB 2844	.....	0–tr.	tr.–
Erect milo[c]	KB 2845	.....	tr.–5	tr.–tr.+
Fargo Straightneck	CI 809	10	0–tr.	0–tr.–
Kaoliang				
Dwarf Shantung	CI 293	40	0–tr.	0–tr.–
Manchu Brown	CI 191	60	50–80	40–65
Broomcorn				
Evergreen	CI 583	0–tr.	tr.–20	tr.
Acme	CI 243	20	tr.–40	tr.
Scarborough	CI 817	.....	20–60	20–60
Black Spanish	CI 826	.....	.....	20–60
Miscellaneous varieties and hybrids				
Weskan	KB 2522	tr.–2	tr.–20	5
Dwarf Hegari	KB 2518	20	5–60	20
"	KB 2537	tr.–5	20–60	20
White Yolo	KB 2525	40	tr.–40	0–tr.–
" durra	CI 81	tr.–5	40–70	20
Darso	KB 2536	tr.–2	tr.–40	10–20
Schrock	KB 2541	tr.–2	tr.–40	0–tr.–
Shallu	CI 85	tr.–2	0–tr.	0–tr.–
"	KB 2879	.....	0–tr.	0–tr.–
Pierce kaferita	KB 2547	tr.–20	20–40	tr.–10
"	KB 2549	tr.–5	tr.–30	tr.+
"	KB 27100	30	.....	.....
"	KB 27101	20	tr.–40	.....

TABLE 1.—*(Continued)*

Variety	Serial number	Range in rust percentage		
		1927	1928	1929
Premo (feterita × kafir)	FCI 8929	30	tr.–20	tr.–5
Chiltex (" ")	FCI 8917		0–tr.	
Red Amber × feterita	KB 2501	25	60–80	20–30
" "	KB 2503	60		
" "	KB 2507	60		
" "	KB 2508	50		
" "	KB 2509	25	20–60	tr.–
" "	KB 2513	25	30–70	15–25
" "	KB 2526	60		
" "	KB 2527	40		
" "	KB 2529	5–60		
" "	KB 2530	30		
" "	KB 2552	20	10–60	20–25
" "	KB 2562	60	40–70	25–40
" "	KB 2567	50	20–60	25–40
" "	KB 2570	40	40–70	5–40
" "	KB 2573	60	20–60	20–25
" "	KB 2574	40		
Blackhull × Sourless	KB 2505	40	tr.–40	
" "	KB 2799	5–20		
Kafir × feterita	FCI 8920	40	20–60	20–40
" "	FCI 8929	35		
" "	HC 2423	40	tr.–40	
Milo × feterita	FCI 8926	25	20–40	tr.–
Kafir × milo 26–3–1–1	KB 2561	20	tr.–20	tr.–
" " 38–1–2–1	KB 2679	40	5–40	tr.–5
Smith's milo × kafir	CI 808	tr.–10		
Kansas Orange × Dwarf Yellow milo	KB 2680	tr.–2	0–5	0–tr.
" "	KB 2681	10	tr.–40	0–tr.
" "	KB 2682	40		
" "	KB 2683	40		
" "	KB 2684	tr.–5	0–5	0–tr.
" "	KB 2685	tr.–5		
Dwarf Yellow milo × Pink kafir	HC 244	tr.–5	tr.	tr.–
" "	HC 257	tr.–5	tr.–40	tr.–
" "	HC 2510	20	tr.–40	tr.–
Feterita hybrid (milo × feterita)	FCI 8926	30	40–80	
Sudan grass				tr.–

[a] KB, HC, FCI, CI, SPI indicate accession numbers of the Department of Botany and Plant Pathology, Kansas Agricultural Experiment Station; Fort Hays Branch Experiment Station, Hays, Kansas; and of the offices of Forage Crops and Diseases, Cereal Crops and Diseases, and Foreign Plant Introduction, of the United States Department of Agriculture, respectively.

[b] A milo type segregate from a kafir × milo 332–1 cross received from J. B. Sieglinger, Woodward, Oklahoma.

[c] A straightneck milo type resembling Fargo Straightneck but much later maturing. Seed from E. E. Senser, Bison, Kansas, who stated he obtained seed in Oklahoma.

As a group, the milos are highly resistant to rust. The highest percentages were noted on varieties of milo in 1927, but in no case was more than 20 per cent seen. A few lowermost leaves of the plants had a moderate amount of rust in that season, but most leaves showed only a very small amount of rust. In many cases but few scattered uredinia were present. In 1928 and 1929 most varieties of milo showed only an occasional uredinium, although one selection of Dwarf Yellow milo and one of Erect milo had an infection of tr-5 per cent in 1928. Hybrids having milo as one of the parent varieties varied considerably in their reaction, although most of them were somewhat resistant. Milo × feterita hybrids seem more susceptible than milo × kafir, Kansas Orange × Dwarf Yellow milo, and Dwarf Yellow milo × Pink kafir hybrids. The two latter crosses contain several highly resistant selections.

Only two varieties of kaoliang were tested at Manhattan. Dwarf Shantung was very highly resistant in 1928 and 1929, while Manchu Brown was highly susceptible all three seasons. In 1927 Dwarf Shantung had considerable rust, especially on certain plants. It is possible that a resistant plant was selfed in 1927, thus establishing a resistant pure line. This is not known to be the case, however, and it may be that a difference in physiologic forms is responsible for the difference in reaction in different years. It is, however, certain that Manchu Brown is a very susceptible variety. It is also extremely susceptible to bacterial stripe. In each of the three years the leaves of this variety were prematurely killed by a combination of extremely heavy infections of rust and bacterial stripe and were thoroughly dry more than half way up the stalk.

Varieties of broomcorn seem to differ considerably in their reaction to rust. Evergreen (standard), CI No. 583, and Acme (dwarf), CI No. 243, were resistant or moderately resistant, while Scarborough and Black Spanish were susceptible. Evergreen, however, seemed to be more resistant than Acme. Thus we have one standard type (Evergreen, C. I. No. 583) resistant and another standard type (Black Spanish) susceptible. The same condition obtains in a general way for the dwarf types. Acme is moderately resistant, while Scarborough is susceptible.

Among the miscellaneous varieties Dwarf hegari, White durra, and darso seemed to be rather susceptible. In 1928 White durra was very susceptible and, in general reaction, the variety seemed to be the same in 1929, although the rust percentage was not high. White Yolo was moderately susceptible in 1927 and 1928 but did not show much infection in 1929. The susceptible reaction of this variety is interesting, since, in several other ways, such as resistance to covered kernel smut, it is very similar to milo. The two selections of shallu were highly resistant to rust in all of the seasons in which they were studied. Shallu seems to be the

most resistant sorghum encountered at Manhattan in the course of these studies. It does not develop red or purplish anthocyanin like most of the sorghums and rust uredinia are therefore not accompanied by the usual red necrotic areas. Several other varieties show the same character to a lesser extent. Leoti Red rarely develops any anthocyanin and there is seldom any in Freed sorgo. The milos, in the field, also show reddening less frequently than most other groups and bear uredinia unaccompanied by red, necrotic areas.

The results of the three years' observations on sorghums at Manhattan very clearly show wide varietal differences in reaction to rust. General statements concerning the reaction of varieties comprising the various groups can be made only with reservations. It can be stated with only occasional exceptions that the kafirs and sorgos are moderately susceptible, the feteritas are very susceptible, and the milos highly resistant. The kaoliang, broomcorn, and miscellaneous groups contain both resistant and susceptible varieties.

The occurrence of *Puccinia purpurea* on sorghum has been reported frequently from Oklahoma, but no data can be found on the reaction of varieties to rust in that State. One of the writers visited the agricultural experiment stations at Stillwater and Woodward, Oklahoma, in the fall of 1927, and there he made a few observations on sorghum rust.

At Stillwater, on September 18, most of the varieties of sorghum had been harvested and only a few were available for study. Rust infection seemed to have been rather light there that season and only small percentages were noted on Blackhull kafir, darso, and feterita.

The amount of rust infection noted at Woodward, on September 19, seemed somewhat higher than that at Stillwater. This was interesting since Woodward is a typical dry-land station, where the average annual rainfall is about 24 inches. The rainfall in the late summer of 1927, however, seems to have been sufficient for the development of considerable rust on sorghum. The amount of infection even on the most susceptible varieties was by no means so heavy as that noted at Manhattan, and it is doubtful if the notes collected do more than point out the susceptible strains. Rust notes were taken on 39 varieties and strains. Blackhull kaoliang and African kafir, CI No. 802, seemed to be very susceptible, while Dwarf feterita, Pink kafir, Sunrise kafir, darso, and Shantung kaoliang were only moderately susceptible. Early Red, Wonder, and Bishop kafirs, and Sourless (African Millet) and Sumac sorgos were free from rust. The amount of infection, however, was too low to render a zero reading very significant. In general, the observations made at Woodward agree with those made at Manhattan, but the percentages at the former station were too low to permit more than a very general comparison.

SORGHUM RUST IN INDIANA

The only observation of sorghum rust in Indiana was made in 1927, when Dr. M. W. Gardner collected this rust in one spot in a field in Tippecanoe County, on October 19. Infection in this limited area was severe. The field was planted with Sagrain (Schrock) sorghum from seed obtained from Texas.

Since this rust had received very little investigation, it was decided to make a study of the relative susceptibility of sorghum varieties received from the Kansas Agricultural Experiment Station and the Office of Cereal Crops and Diseases. This study was made in the field during the summers of 1928 and 1929 and upon seedlings in the greenhouse during the winters of 1927–1928, 1928–1929 and 1929–1930. The results are given in tables 2 and 3.

In 1929 a number of additional varieties were received from the Kansas Agricultural College, which were studied only in the seedling stage in the greenhouse. These reacted as follows:

Very susceptible, the uredinia accompanied by pronounced purpling; Acme broomcorn CI 243, Scarborough broomcorn KB 30107, Blackhull kafir KB 2539, Club kafir KB 2828, Early Pink kafir KB 2824, Farmer kafir KB 2554, Pink kafir KB 2506, Pink kafir KB 2546, Reed kafir KB 2502, Sunrise kafir KB 2523, Western Blackhull kafir KB 27102, Feterita KB 2690, Red Leaf feterita KB 2544, Atlas sorgo KB 2877, Kansas Orange sorgo KB 2572, Kansas Orange sorgo KB 2560, White African sorgo KB 2521, Manchu Brown kaoliang CI 171, Pierce kaferita KB 2547, Premo FCI 8929, Sharon kafir KB 27106, White Yolo KB 2525, Kafir × milo 38–1–2–1, Kansas Orange × Dwarf Yellow milo KB 2681, Red Amber × feterita KB Nos. 2501, 2509, 2513, 2552, 2562, and 2570.

Very susceptible, the uredinia accompanied by moderate purpling; Evergreen broomcorn CI 583, Juicy Pink kafir FCI 9091, Red kafir KB 2545, Pink Freed KB 2798, Dwarf Yellow milo × pink kafir HC 257.

Moderately susceptible the uredinia accompanied by pronounced purpling; Blackhull kafir KB 2569, Dawn kafir KB 2538, Dawn kafir HC 2421, Dwarf Sumac sorgo KB 2576, Honey sorgo KB 2874, Weskan sorgo KB 2522, Wonder kafir KB 2520, Wonder kafir KB 2548, darso KB 2536, Pearl kafir KB 27104, Pierce kaferita KB 2549, Pierce kaferita KB 27101, milo × feterita FCI 8926, kafir × feterita HC 2423, Red Amber × feterita KB 2567 and KB 2573.

Moderately susceptible, uredinia accompaniel by moderate purpling; Dwarf Freed sorgo KB 27107, Freed sorgo KB 2519, Modoc Pink Freed sorgo HC 2520, Red Amber sorgo KB 2504, Dwarf hegari KB 2518, Dwarf hegari KB 2537, Rice kafir KB 27105.

Moderately susceptible, uredinia not accompanied by purpling; "Japanese Honey Drip" sorgo KB 2896, Leoti Red sorgo FCI 6610, shallu CI 85, White durra CI 81.

Very resistant, uredinia few, small, accompanied by pronounced purpling; Bishop kafir CI 814, milo × feterita FCI 8926.

Highly resistant, no uredinia produced, infection evident as small purplish flecks; Dwarf White milo FCI 8927, Dwarf Yellow milo KB 2515, Dwarf Yellow milo KB 2556. Dwarf Yellow milo KB 2564, Fargo Straightneck milo CI 809, Standard White milo CI 352, Standard Yellow milo CI 234, Lasely sorgo KB 2571, Dwarf Shantung kaoliang CI 293, Schrock KB 2541, Dwarf Yellow milo × Pink kafir HC 244, HC 2510, Kafir × milo 26–3–1–1, Kansas Orange × Dwarf Yellow milo KB 2680, Kansas Orange × Dwarf Yellow milo KB 2684, Smith's milo × kafir CI 808. Shallu KB 2879 was highly resistant, showing only a few very indistinct flecks.

In both field and greenhouse tests at Purdue University all the strains of Milo (Fig. 2, A, and Fig. 3) were highly resistant to *Puccinia purpurea*.

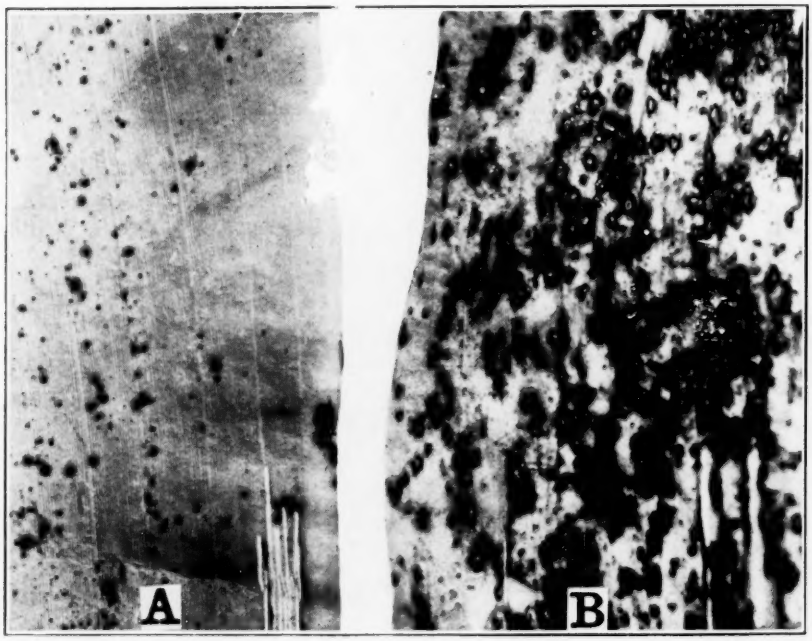

FIG. 2. A. A portion of a leaf of the highly resistant Dwarf Yellow milo showing small purplish flecks without uredinia. B. A portion of a leaf of very susceptible feterita showing large uredinia surrounded by large purplish spots. Leaves from field plantings, La Fayette, Indiana, 1928.

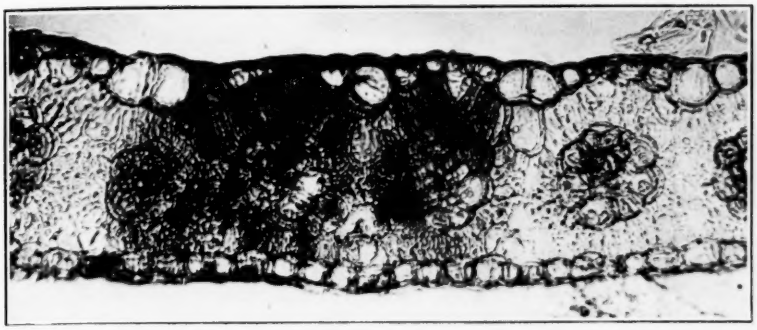

FIG. 3. Section through leaf of very resistant milo infected with *Puccinia purpurea* showing purplish discoloration of the small infected area and absence of uredinia. Compare with figures 6 and 7.

Dwarf Shantung kaoliang KB 2565 (CI 293) (Fig. 4, B), Lasley sorgo KB 2571, Bishop kafir CI 814, shallu KB 2879 (Fig. 4, C), Schrock KB 2541 and hybrid selections HC 244, HC 2510, KB 2561, KB 2679, KB 2684, KB 2678 from crosses with milo were the most outstanding for resistance in

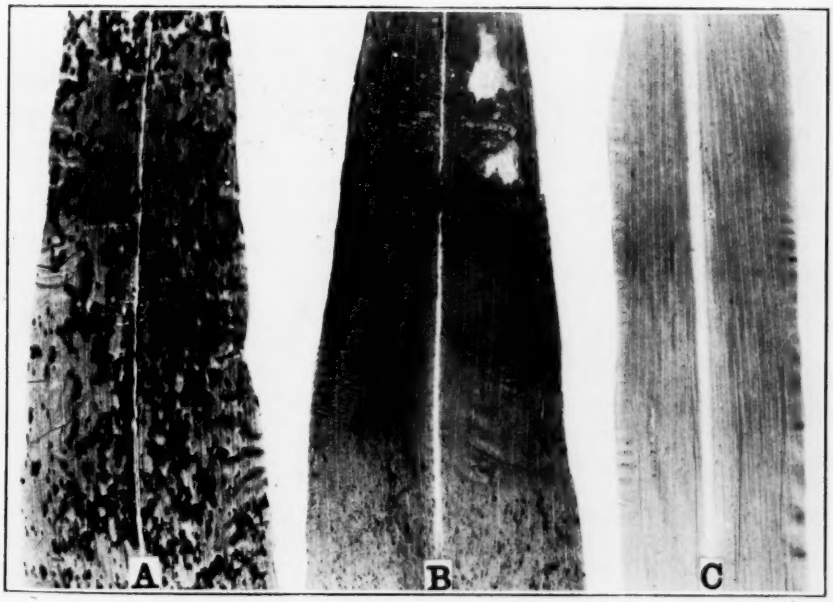

FIG. 4. Comparative reaction of sorghum varieties. A. Red kafir, moderately susceptible with large uredinia in purplish spots. B. Dwarf Shantung kaoliang, very resistant, infection indicated only by slight purplish flecks, no uredinia. C. Shallu, very resistant, infection indicated only by extremely few indistinct flecks, no uredinia. Leaves from field plantings, La Fayette, Indiana, 1928.

TABLE 2.—*Relative reaction of sorghum varieties to Puccinia purpurea in field and greenhouse tests at La Fayette, Indiana. 1928–1929*

Variety	Acc. No.[a]	Rust reaction		
		Field[b]	Greenhouse[c]	
		1928	1928	1929
Kafir				
Reed	KB 2502	tr.–25P	4P	3P
Sunrise	KB 2523	50–100P	4P	3P
Blackhull	KB 2535	5–15P	4P	
Dawn	KB 2538	25–50P	4P	3p
Red	KB 2545	75–100P	4p	
Reed	CI 628	15–35P	4P	3p
Red	CI 34	35–65P	3–4P	4p
Dawn	CI 340	50–65P	3–4P	4P
Blackhull	CI 310	50–100P	4P	3P
Sorgo				
Freed	KB 2519	50–65P	3–4p	3p
White African	KB 2521	50–65P	3–4p	
Fielding Sumac	KB 2553	50–100P	4P	3P
Kansas Orange	KB 2560	15–25P	3–4P	3P
Leoti Red	KB 2575	50–100	4	3
Dwarf Sumac	KB 2576	75–100P	3–4P	
Red Amber	FCI 17548	50–75P	4p	4P
Leoti Red	FCI 6610	50–65P	3–4	3
Kansas Orange	FCI 9108	35–50P	4P	4P
Freed	CI 350	50–65P	3–4P	
Saccaline	FCI 48191	25–50P	3–4P	4P
Sourless	FCI 9074	50–75P	4P	4P
Atlas	FCI 9112	50–65P	4P	4P
Black Amber	FCI 7038	50–100P	4P	4P
Feterita				
Standard feterita	KB 2563	75–100P	3–4P	
"	SPI 51989	50–75P	4P	4P
"	SPI 51991	50–75P	4P	3P
"	CI 182–1	75–100P	4P	3P
"	CI 182	50–100P	4P	3P
Milo				
Dwarf Yellow	KB 2512	0P	0P	tr.P
Standard Yellow	CI 234	0–tr.P	0P	0P
" White	CI 352	0p	0P	0p
Fargo Straightneck	CI 809	tr.–15P	0P	
Dwarf Yellow	CI 332	tr.–15P	0P	0p
Kaoliang				
Dwarf Shantung	CI 293	0P	0P	0p

TABLE 2.—(*Continued*)

Variety	Acc.[a] No.	Rust reaction		
		Field[b]	Greenhouse[c]	
		1928	1928	1929
Broomcorn				
Acme	KB 2558	15–25P	3–4p	3P
"	CI 243	50–75P	4p	4P
Miscellaneous				
Shallu	CI 85	0	3–4	
Dwarf Hegari	KB 2518	50–65P	4P	3P
"	CI 620	50–100P	4P	
Schrock	KB 2541	75–100P	4P	4P
"	CI 616	25–35P	3–4P	3P

[a] Accession numbers of the Department of Botany and Plant Pathology, Kansas Agricultural Experiment Station, and of the offices of Forage Crops and Diseases, Cereal Crops and Diseases, and Foreign Plant Introduction, of the United States Department of Agriculture.

[b] Percentage of rust, the total amount possible being taken as 100%. Notes taken in September.

P = Pronounced purpling accompanying uredinia.

p = Purpling less pronounced. Where no letter is given no purpling was noted.

[c] Numerals indicate type of reaction; 4, very susceptible; 3, moderately susceptible; 2, moderately resistant; 1, very resistant; 0, highly resistant, no uredinia produced.

the other groups studied. Usually no uredinia were produced. Only small purplish flecks indicated that infection had occurred, and sometimes these were very indistinct, as in the case of shallu (Fig. 4, C). Most of the other varieties were more or less susceptible, differing mostly in the number of uredinia produced. This was most marked in the field planting in 1928 (Table 2). Thus, while such varieties as Schrock, Leoti Red sorgo, and Dawn kafir did not differ much in the seedling stage in the greenhouse, in the field they showed considerable difference in amount of rust, as indicated in table 2 and figure 5. A number of the kafirs were only slightly to moderately rusted, most of the sorgos were moderately to heavily rusted, while all of the feteritas were heavily rusted.

As has been noted, infection of the sorghums usually results in the production of a purplish discoloration. This takes place both in resistant and susceptible varieties. Thus, while uredinia are not produced on milo, small purplish spots develop (Fig. 2, A). The purplish areas on susceptible varieties such as feterita are, however, much larger (Fig. 2, B, Fig. 6), probably corresponding to the area occupied by the mycelium. A few

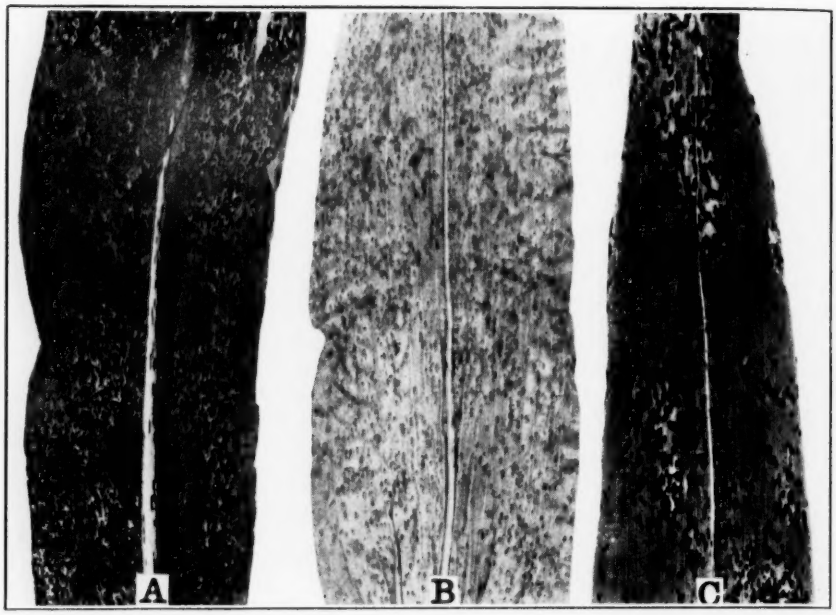

FIG. 5. A. Schrock, very susceptible, uredinia abundant in pronounced purplish spots. B. Leoti Red, moderately susceptible, uredinia fairly abundant, no purpling. C. Dawn Kafir moderately susceptible, uredinia fairly abundant in pronounced purplish spots. Leaves from field planting, La Fayette, Indiana, 1928.

varieties, however, do not develop purplish color in the infected areas. Leoti Red sorgo FCI 6610 (Fig. 5, B, Fig. 7), "Japanese Honey Drip" sorgo KB 2876, shallu CI 85, and White durra CI 81 were more or less susceptible varieties which produced little or no purpling. Shallu CI 85 and KB 2879 (Fig. 4, C), among resistant varieties, showed little or no development of purple in infected areas. The occurrence of purple, therefore, seems not to be due to the effect of the fungus on the host but to the presence of factors for color development in certain varieties.

A few grass sorghums also were studied in 1929 in the greenhouse. Sudan grass KB 2981, FCI 17540, and Johnson grass FCI 15879 were very susceptible, accompanied by pronounced purpling, and Tunis grass FCI 38108 was moderately susceptible, with pronounced purpling. Fifteen unnamed grass sorghums were also received from Mr. H. N. Vinall of the Office of Forage Crops and Diseases, United States Department of Agriculture. Of these, Nos. 50790, 52000, 52022, 52044, 52062, and 52124 were very susceptible, with pronounced purpling; Nos. 49697, 50008, 50079, 52026, 52132, and 58742 were moderately susceptible, with pronounced purpling; Nos. 51995, 52050, and 52053 were highly resistant, no uredinia being formed, infection being evident as slightly purplish flecks.

FIG. 6. Section through uredinium of *Puccinia purpurea*, from susceptible feterita, showing paraphyses, urediniospores, and marked purpling of the infected tissue. Compare with figures 3 and 7.

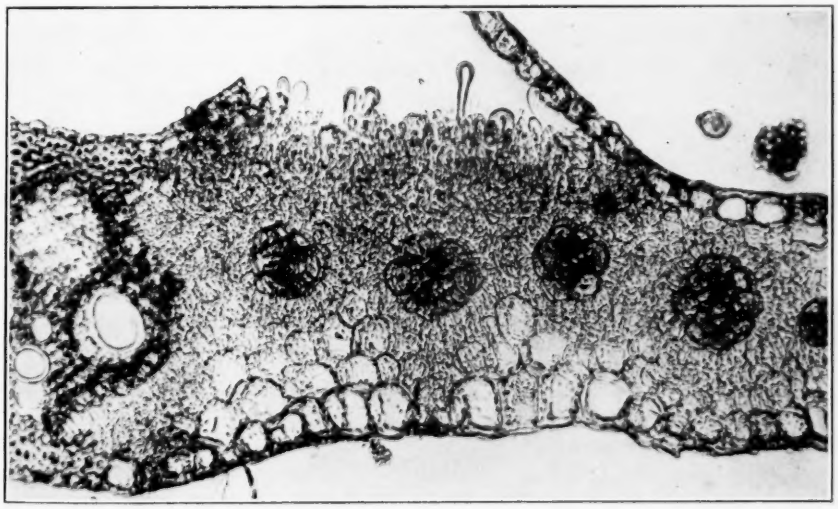

FIG. 7. Section through uredinium of *Puccinia purpurea* from the susceptible variety Leoti Red sorgo showing paraphyses and absence of purplish coloration in the infected tissue. Compare with figures 3 and 6.

TABLE 3.—*Reaction of seedlings of a selected set of sorghum varieties to four cultures of Puccinia purpurea in greenhouse, La Fayette, Indiana. 1930*

Variety	Acc. No.[a]	Culture numbers[b, c]			
		2	3	4	5
Standard Yellow milo	KB 2524	0P	0p	0P	0P
Acme broomcorn	KB 2558	4p	4p	4p	4p
Blackhull kafir	KB 2539	4P	4p	4P	4p
Dawn kafir	KB 2538		3p		4p
Dwarf White milo	KB 2566	0P	0p	0P	0p
Dwarf Yellow milo	KB 2515	0P	0P		0P
"	KB 2564	0P	0P	1P	0P
Fargo Straightneck milo	KB 2677	0P	0P	0P	0p
Standard White milo	KB 2533	0P	0P	1P	0P
Kansas Orange sorgo	KB 2572	4p	4p	4p	3p
Lasley sorgo	KB 2571	0P	0p	0P	0p
Dwarf Shantung kaoliang	KB 2565	0p	0p	0p	0p
"	KB 2565 Sel.	0p	0p	0p	0p
Manchu Brown kaoliang	KB 2568	4P	4P	4P	4P
Bishop kafir	KB 27103	0P	0p	1P	0p
Wonder "	KB 2548	4P	4P	4P	4p
Darso	KB 2536	4P	4P	4P	4P
Dwarf hegari	KB 2537	4p	4P	4p	4P

[a] Accession number of the Department of Botany and Plant Pathology, Kansas Agricultural Experiment Station.

[b] Type of reaction. 4, very susceptible; 3, moderately susceptible; 2, moderately resistant; 1, very resistant; 0, highly resistant, no uredinia.

[c] 2 collected at Manhattan, Kansas, on Standard White milo 352, Aug. 29, 1929.
3 collected at Manhattan, Kansas, on feterita CI 182, Aug. 29, 1929.
4 collected at Manhattan, Kansas, on Scarborough, September 3, 1929.
5 collected at La Fayette, Indiana, September 19, 1929.

Corn having been reported as a host for *Puccinia purpurea*, the sorghum rust was sown on 384 inbred lines of corn. These include lines of Howling Mob, Golden Bantam, Golden Rod, and Narrow Grained Evergreen sweet corns, Ball pop corn and Golden Glow, Early Yellow Dent, Reid's Yellow Dent, and Lancaster County dent corns. No signs of infection were noted on these.

To determine whether sorghum varieties might serve as hosts of corn rust, *Puccinia sorghi*, 115 strains and varieties of sorghum were inoculated with physiologic form 1 of *P. sorghi* in the spring of 1929, in the seedling stage, in the greenhouse. These included all of the strains and varieties studied for reaction to *P. purpurea* in 1929. Uredinia did not develop on any of these. In most cases a very faint purplish flecking was noticed.

SUMMARY

Rust (*Puccinia purpurea*) was found on sorghums as far north as La Fayette, Indiana, and Manhattan, Kansas, in 1927. The disease also was seen on sorghums in Oklahoma in the same year.

Rust readings were made on the varieties grown in the field at Manhattan in the seasons of 1927, 1928, and 1929, and in the field and greenhouse at La Fayette in 1928, 1929, and 1930.

Varieties of sorghum were found to vary considerably in their reaction to rust. In general, the kafirs and sorgos seemed to be moderately susceptible, while the feteritas were very susceptible and the milos very resistant.

Both resistant and susceptible varieties were found in kaoliang and broomcorn.

In the field shallu proved to be highly resistant in all years, while White durra was susceptible.

Hybrids between several varieties gave varying reactions, depending upon the varieties used in crossing.

Several unnamed grass sorghums, Johnson grass, Tunis grass, and Sudan grass proved to be susceptible, while several other unnamed grass sorghums were resistant.

Pronounced purpling accompanied the uredinia on most varieties, but none was observed in shallu CI 85, White durra CI 81, and Leoti Red FCI 6610, and "Japanese Honey Drip" KB 2896 sorgos. These varieties apparently lack factors governing the development of red pigment in foliar tissues.

No definite evidence of the occurrence of physiologic forms was obtained.

Puccinia purpurea failed to cause infection in varieties of dent and sweet corn, and no infection resulted from the inoculation of varieties of sorghum with *P. sorghi* physiologic form 1.

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THE IMPORTANCE OF INVESTIGATIONS ON THE EFFECTS OF KNOWN MIXTURES OF MICROORGANISMS[1]

HOWARD S. FAWCETT

Investigation with one microorganism kept pure and free from contamination with any other has been the classical procedure ever since Koch and others perfected the pure-culture methods that facilitate so greatly the separation of microorganisms. Students in our laboratories have been thoroughly imbued with the idea that cultures must be pure for a single organism. This necessary insistence on pure cultures of single organisms has perhaps led unconsciously to a feeling that to allow the use of a mixture in plant-pathological work is extremely unscientific if it is not actually a "*deadly plant pathological sin.*"

The insistence on purity of cultures was, indeed, a very important condition in preliminary work for the study of the part played by single organisms in the absence of all others. The work with one organism at a time was a necessary stage of analysis. I feel, however, that we have now come to a stage requiring synthesis as well as analysis, integration as well as differentiation. We are not, it would seem, getting the whole plant-pathological story by working solely with pure cultures of single organisms. Nature does not work with pure cultures alone but most frequently with associations. No mathematician would be satisfied to take his student only through differentiation in calculus but would push on to the all-important stage of integration. Rahn (17), in microbiology, pointed out clearly the importance of a study of the mutual influence of microorganisms when he said "The experience obtained with pure cultures is not sufficient to explain all microbial activity in nature."

In view of these considerations I feel we are ready as plant pathologists to enter more actively into the investigation of the effects of known mixtures in comparison with the effect of the individual organisms alone in their relation to disease. Pure cultures we must, of course, continue to use as a basis for the known mixtures and as controls on the activity of the mixtures. Is it not just as scientific and free from criticism for us to work with known mixtures of fungi as it is for a chemist to work with known mixtures of chemical compounds? Numerous examples in chemistry come to mind at once where mixtures in solutions bring about definite things that none of the components can accomplish when acting alone. A classical example is the mixture of acids in *aqua regia* and also the action of numerous catalysts. Research with mixtures of microorganisms will not,

[1] Presidential paper presented at Twenty-second Annual Meeting of the American Phytopathological Society at Cleveland, Ohio, December 30, 1930.

however, furnish an excuse for any less care than with pure cultures in excluding organisms foreign to the given mixtures.

A small beginning in this line of research has been made by various workers, but there appears to be a wide-open field for more investigation in this subject, especially in plant pathology.

There are two phases out of many possible ones in this subject that I believe will be highly productive of results in research: (1) the study in a quantitative as well as qualitative way of the effect of known mixtures or combinations of microorganisms in culture media; (2) the study in the same way of the effect on development of disease by inoculation of plants with known mixtures of microorganisms. A considerable number of publications have appeared bearing directly or indirectly on the first phase of the subject, but only a limited amount of literature has been found on the second.

The literature on the effects of association of organisms in cultures has been recently reviewed by Buchanan and Fulmer (2), especially for bacteria; by Porter (16); and by Machacek (10), especially for fungi. The type of association in which different organisms, growing together, bring about effects which any one of them growing alone is unable to accomplish has been called "synergism" by Holman and Meekison (9). Some striking examples of synergism may be mentioned.

Waksman and Lomanitz (24) have shown that *Bacterium cereus* and *Bact. fluorescens*, growing together, can bring about formation of ammonia from proteins. The first can act only on the protein to form amino acids, the second only on the amino acid to form ammonia.

Sherman and Shaw (21) found that the rate of fermentation of lactose to form propionic acid was speeded up very greatly by the combination of either *Streptococcus lacticus* or *Lactobacillus casei* with *Bacterium acidi-propionici*.

Marshall and Ferrand (11) found that more than half of the organisms usually present in milk, when grown in combination with lactic microorganisms, accelerated the growth and the action of these lactic-acid formers.

Cellulose decomposition was found by Sanborn (18) to be greatly aided by the association of certain microorganisms in a cellulose medium with *Cellulomonas folia*. The cells of the associated organisms were thought to furnish some essential food substances which stimulated the growth and physiological efficiency of the cellulose destroyer.

Examples of both accelerated and retarded or inhibited growth in mixed cultures of fungi as compared with growth of one alone were found by Harder (8) and by Zeller and Schmitz (25). Harder has given a good review of the literature preceding 1911. In Alternaria cultures Elliott (4,

p. 463) noted profound effects on the growth and form of the hyphae when certain bacteria were present.

It was determined by McCormick (12) that the fungus *Thielavia basicola*, when grown in pure culture, usually failed to produce perithecia but, when combined with certain other fungus species, perithecia were readily formed. The same relationship between species of Ascobolus and certain bacteria was found by Molliard (14).

Machacek (10), in carrying out a large amount of quantitative work with different pairs of fungi in cultures, found examples of (1) mutual tolerance and (2) partial or complete inhibition of one by its associate, the degree of inhibition depending somewhat on temperature and number of spores. Many other examples of synergism or associated action might be mentioned in connection with bacteria and fungi in cultures.

In the second phase of the subject—that of the effect of known mixtures or combinations of organisms on the occurrence and development of diseases—the literature appears to be rather limited, although the idea is by no means new and, recently, is receiving more attention. Some examples that I have been able to find, including those of my own experiments, will be mentioned.

In Florida, Fawcett (5), found that *Diplodia natalensis* and *Colletotrichum glocosporioides*, inoculated simultaneously in slight wounds in citrus bark, produced much more marked effect than when each was applied alone. The same was true of a combination of *Phomopsis citri*, *D. natalensis*, and *Cladosporium herbarum* var. *citricolum*. Later, in California, the same author (6) showed that inoculations of *Phytophthora citrophthora* combined with *Fusarium* sp. produced much more rapidly enlarging lesions of Pythiacystis gummosis than did the inoculation with *Phytophthora citrophthora* alone. The *Fusarium* sp., when introduced alone, was unable to advance at all in this wounded bark. This was a case of a saprophytic organism greatly aiding a parasitic one. The opposite effect, or negative synergism, was shown when mixtures of the walnut Melaxuma fungus, *Dothiorella gregaris*, and the walnut blight bacterium, *Pseudomonas juglandis*, were inoculated into large walnut branches (7, p. 38). The mixture resulted in an almost complete inhibition, no lesion being formed, while *D. gregaris* alone was capable of producing large lesions, some of which girdled and killed the branches.

In line with this latter effect are the results recorded by Millard and Taylor (13) with potato scab. They found that a mixture of a pathogene, *Actinomyces scabies*, and a saprophyte, *A. praecox*, in soil in pots reduced the occurrence of scab sometimes to a negligible amount as compared with action of the parasite when applied alone. Great inhibition in the infection of wheat seedlings was reported by Porter (16) as the result of mixing

certain bacteria in the same soil with Helminthosporium and delay in the infection of flax seedlings by mixing bacteria with Fusarium in the same soil. At the Des Moines meeting of the American Phytopathological Society, Plakidas (15) stated that a mixture of nine strains of Pythium was less severe in producing a root rot of strawberries in Louisiana than any one of the pathogenic strains alone. Bamberg (1) reported at the same meeting that an inoculum containing a mixture of *Ustilago zeae* and a certain bacterium almost entirely failed to produce smut in maize.

Not to neglect the field of virus diseases, a certain type of streak disease of tomatoes has been reported by Dickson (3) and Vanterpool (23) and confirmed by others, to be produced by a mixture of potato-mosaic and tomato-mosaic virus. That other virus mixtures may produce effects not accomplished by either component alone has been recently reported by Valleau and Johnson (22).

The most extended recent work with mixed inoculations appears to be that of Machacek (10) on apple fruit and that of Savastano and Fawcett (19) on citrus fruit. Machacek obtained with apple-rot fungi an increase of decay with some mixtures and a decrease with others, depending to some extent on the temperatures. The results of the mixed inoculations of Savastano and Fawcett (19) showed striking examples of (1) both accelerating and depressing effects of certain mixtures as compared with the effect of any one of the organisms acting alone; (2) the selective effect of temperature, in many cases enabling one organism in a mixture to dominate the others in producing decay; (3) the influence of certain mixtures on changes in color or consistency of decay. Great acceleration was produced by most of the mixtures containing *Oospora citri-aurantii* and some retardation with most mixtures containing *Botrytis cinerea*.

During the past year Savastano and Fawcett (20), in connection with mal secco of citrus in Sicily, found that infection was inhibited or suppressed by a mixture of *Deuterophoma tracheiphila* and *Fusarium* sp., the former alone being able to invade the wood rapidly.

This acceleration or depression of disease caused by a mixture of organisms probably is related in many cases to the combination of enzymes that are present and their action in making food materials for growth available or in producing inhibiting and accelerating substances. The real causes for these phenomena need careful investigation.

I suspect that many plant diseases are influenced by associated organisms to a much more profound degree than we have yet realized, not only as to inhibition, but as to acceleration, of the processes. It may be that a number of diseases may require an association of organisms for their occurrence and cannot be produced by infection of one organism alone.

These considerations appear to indicate an inviting field for much more extended research. Work with mixtures, however, will not make the already complex problem of plant pathology as a whole any easier or less complex, but it may throw much light on certain relationships, relationships which will probably never be discovered by the use of pure cultures of single organisms. We cannot, therefore, in my judgment, avoid entering actively into this largely unexplored field.

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SOIL CULTURES FOR THE LABORATORY PRODUCTION OF SCLEROTIA IN PHYMATOTRICHUM OMNIVORUM[1]

B. F. Dana

The production of true sclerotia in pure cultures of the cotton root-rot fungus, *Phymatotrichum omnivorum* (Shear) Duggar, was first reported by King and Loomis (2, 3) and later by Neal (4) and Taubenhaus and Ezekiel (6). These workers used pure cultures as sources of inoculum and sterilized mixtures of soil, sand, and plant materials as media. In these cultures, the fungus was not obliged to compete with other organisms. The conditions under which sclerotia developed were entirely artificial and not directly comparable with the conditions under which sclerotia are produced in nature.

It is the purpose of this paper to describe cultures, brief mention of which appeared in an earlier popular report (1), more nearly approximating field conditions than those noted above. The work herein described parallels, in part, that of Taubenhaus and Ezekiel (5, 6).

Non-sterilized field soil of suitable moisture content is used as a medium. In this is placed the inoculum, which consists of newly-diseased roots of one of the many susceptible plants. The use of soil and diseased plant parts without special preparation is especially simple. The results vary with the different materials used and other fungi, as well as insects, are troublesome at times. The ready and abundant production of sclerotia, however, and the adaptability of these cultures to the study of field factors affecting sclerotial production make it seem desirable to describe in detail the methods used and results secured.

MATERIALS AND TECHNIQUE

Containers: Erlenmeyer flasks, damp chambers, and fruit jars of various kinds and many other types of glass jars have been used. Square mason fruit jars (Fig. 1, B) of quart and 2-quart capacity have been used most extensively because of their availability and reasonable cost. The glass container permitted ready examination of the development of the fungus among the exposed soil particles. The square container also permitted better close-up photographs than round or irregular containers and packed more conveniently into incubators and culture chambers. An ordinary

[1] Presented at the 1930 meeting of the Southwestern Division of the American Association for the Advancement of Science and published with the approval of the Director as Contribution No. 126, Technical Series, Texas Agricultural Experiment Station.

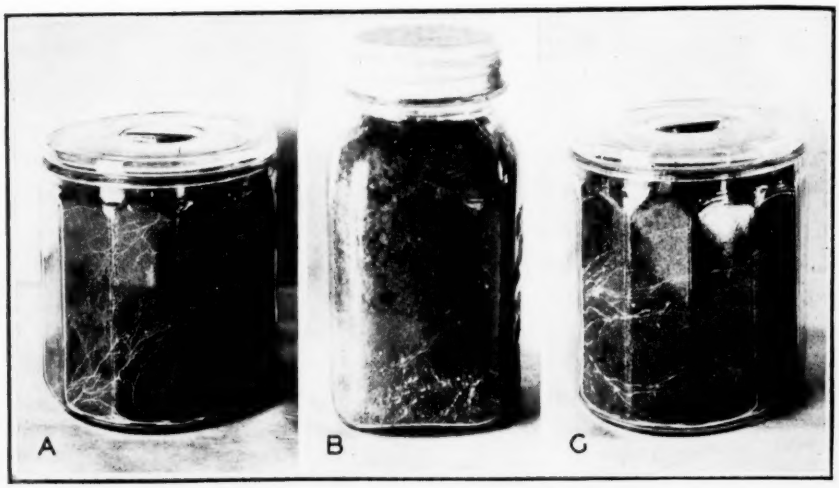

FIG. 1. Soil cultures. A. Cracker jar showing strand growth from cotton inoculum. B. Mason jar showing young sclerotia. C. Cracker jar showing strands and young sclerotia.

commercial cracker jar (Fig. 1, A and C) of about 2-quart capacity provided with loosely fitting cover was used to some extent. In the use of fruit jars the regular mason cover was used without rubbers, for the cultures seemed to develop a little better if the jars were not sealed. A wooden frame with glass sides was constructed for photographic and exhibition purposes. For one experiment a case, much like a museum case, was built up of pieces of glass 18 inches square made tight at the corners with strips of paper. Containers made entirely of wood or metal were not employed because of the difficulty of examining the progress of the culture.

Preparation of cultures: The first cultures to produce an abundance of sclerotia were set up June 5, 1929, in cracker jars of about 1.5 liters capacity and provided with a loose-fitting lid. Houston black-clay soil with a moisture content of about 30 per cent was loosely packed into these jars. Diseased carrots furnished the most readily available infected roots. These were placed in the soil as the jars were being filled. The cultures thus set up were incubated in the laboratory at room temperature, which was then near 27° C.

New strand growth appeared within 24 hours and spread rapidly over the soil particles close to the glass. These strands were, at first, white, later turning darker and finally becoming brownish. At the end of 5 days sclerotia began to appear in these cultures as swellings in the thicker portion of the strands. These newly-formed sclerotia were at first white (Fig. 2, A), turned brownish after a few days, and became reddish brown

(Fig. 2, B) when finally mature. The sclerotia thus formed were variously clustered and lobed and covered with short hyphal branches. In many strands the sclerotia were formed at intervals and presented an appearance not unlike a string of beads. In size these sclerotia ranged from those a little thicker than the strands to those 2 to 3 mm. in diameter. With cotton inoculum many were formed which measured as much as 5 mm. in diameter.

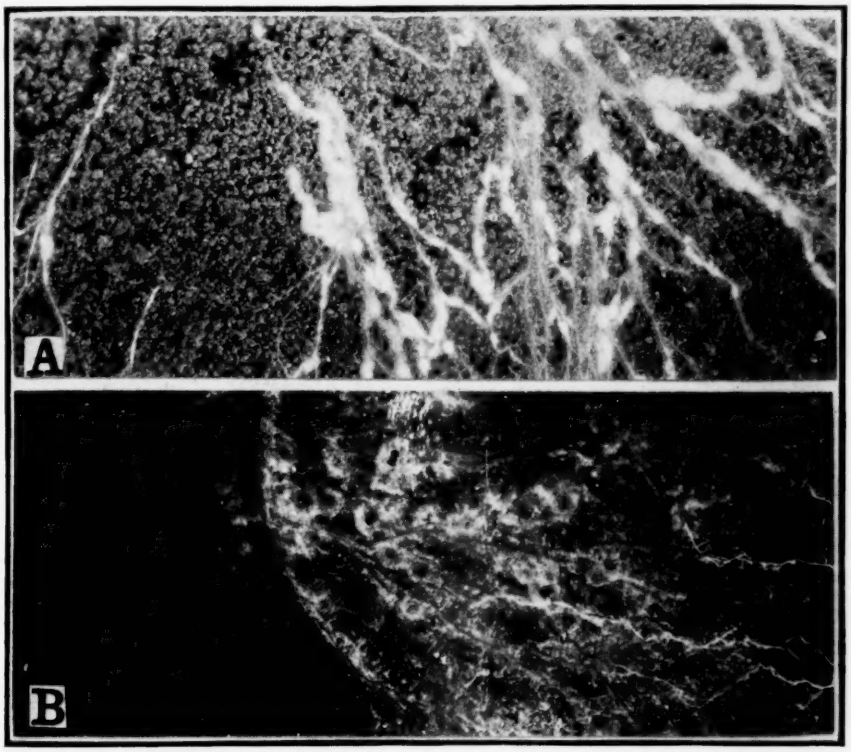

FIG. 2. Sclerotial development in soil cultures. A. Young strands and sclerotia. B. Mature sclerotia.

Inoculum: As already stated, diseased carrots were used as inoculum in the first soil cultures to produce sclerotia. Carrots produced the largest number of sclerotia, while diseased cotton roots produced larger, although fewer, individual sclerotia. Diseased roots of many other plants also were tested, but none of them has compared with cotton and carrot inoculum in the production of large quantities of sclerotia.

The condition of the diseased root was found to be important. Best development of strands and sclerotia was secured from roots with well-

established infections, although with both carrots and cotton the best results were obtained from roots which were not completely covered by the fungus. Roots with incipient infection were found unsuitable, since the fungus failed to make further development after the root was disturbed. Also, roots that had stood in the field until fungus development was checked failed to show any new growth of the organism. This was particularly noticeable in roots procured after the disease was checked by the cooler fall weather. When the fungus was in an active condition it showed a greater tendency to send out strands over the surrounding soil.

Comparative studies indicate that an abundant supply of food material promotes mycelial-mat development, while a substratum less rich in food materials promotes strand and sclerotial development. Sliced healthy carrots and sterilized cottonseed meal were added to soil with diseased-carrot inoculum. In those cultures not invaded by Rhizopus and other fungi the root-rot fungus made an extensive growth of loose mycelium at the expense of strand growth and sclerotial development. In this connection it may be noted that weak corn-meal agar has promoted strand growth, while sterilized corn meal has produced thick mats of mycelium with no individual strands evident. The extension of strands in field soil with its meager food materials is indicated by the behavior of the fungus in the cultures under discussion.

A lessened development of strands was secured, but a more extensive growth of loose wefts of mycelium took place with sterilized soil than with similar non-sterilized soil. In some of these cultures with sterilized soil sclerotia were entirely suppressed, although there was a copious development of loose mycelium. A further study of the food requirements of the fungus is being made which it is hoped may throw further light on the behavior of the parasite in the field.

MOISTURE REQUIREMENTS

The behavior of the fungus in soils of different moisture content was studied by means of these soil cultures. The absolute moisture content for each lot of soil used was determined. It was possible to correlate variations in development of the fungus in different lots of the same soil with differences in moisture content. Tests also were run with the same soil to which were added predetermined amounts of moisture. One such test was set up on August 30, 1929, in which 6 jars were used for each percentage of moisture. The soil and water were thoroughly mixed before the jars were filled. Soil, air-dried to a moisture content of 9 per cent, was used and moisture was added to bring the percentage up to 10, 20, 30, 40, 50, and 60, based on the dry weight of the soil.

In those jars to which 40, 50, and 60 per cent of moisture had been added, growth of the fungus was scant and was confined to the top surface of the soil. Free water collected in all these jars, indicating complete saturation of the soil. Slight growth took place in the jars with 10 and 20 per cent moisture, but it was confined to the vicinity of the carrot inoculum. The most extensive growth of the fungus appeared in the jars of soil with 30 per cent moisture, which indicated that this was the most favorable moisture content for the soil used.

The Houston black-clay surface soil used in the above experiment has been found to have a much higher moisture-holding capacity than the underlying subsoil. It is evident that the optimum moisture content would vary in different soils and would bear a relation to the available water present.

TEMPERATURE REQUIREMENTS

The first sclerotia produced were developed in the laboratory at a period when the mean daily temperatures ranged between 21 and 27° C. Later in the year almost no sclerotial production took place in soil cultures incubated at laboratory temperatures ranging from 5 to 21° C.

Many cultures were run in an incubator at constant temperatures. At 38° C. no sclerotia were formed; a few were formed at 32° C., but a very copious production took place at 27° C. From this preliminary work it is evident that the temperature range favorable for the production of sclerotia in soil cultures of this type lies between 21 and 32° C. It is interesting to note that at depths of 6 to 24 inches, at Substation No. 5, Temple, the soil temperatures fall within this range during the period of the year when root rot is active.

OTHER APPLICATIONS OF SOIL CULTURES

Aside from a study of the factors involved in the development of sclerotia, soil cultures have been used in testing soil disinfectants. Organic mercury, Semesan, mixed with the soil, has inhibited both strand development and sclerotial formation. The cultures have also been used to test the duration of the protective action of various chemicals added to the soil. For this purpose soil from treated plats was collected after the treatment had stood for a period. The soil cultures are adapted also to the laboratory testing of the effect of fertilizers and soil-ameliorating treatments on strand and sclerotial development of the root-rot fungus under field conditions.

SUMMARY

A method is described for culturing *Phymatotrichum omnivorum* in which non-sterilized soil is used as medium and newly-diseased roots as in-

oculum. This type of culture appears to be well adapted to a study of the moisture and temperature requirements for the production of strands and sclerotia in the cotton-root-rot fungus, *P. omnivorum*, under conditions comparable to those found in the field, and to test the effectiveness of chemical and fertilizer applications in cotton-root-rot control.

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THE OCCURRENCE OF VIOLET ROOT ROT IN CENTRAL TEXAS[1]

B. F. Dana and S. E. Wolff

During the summer, fall, and early winter of 1929, violet root rot, caused by *Rhizoctonia crocorum* (Pers.) DC.,[2] was found prevalent in several locations along the courses of the Little and Leon rivers in Bell County, Texas. Preliminary examination indicates that the disease may be generally distributed in the soils along these rivers.

Diseased plants were found in the wooded areas which spread back from the river for a distance of a few rods to half a mile and in the adjoining margins of cultivated fields. The soils of these areas are highly calcareous and vary from clay to clay loam. They are not well drained and are subject to overflow during periods of high water. The vegetation consists of the usual water-course inhabitants. Where the wooded areas are rather wide *Hicoria pecan* Britt. and *Ulmus americana* L. are the dominant species. Societies of shrubs and herbs (Fig. 1, A) are, likewise, pronounced in these areas. Near the stream bed *Salix nigra* Marsh. (Fig. 1, B) is the prevailing species, the individuals of which usually form a dense stand.

The disease did not appear to be selective but was present on nearly all the species of plants growing in the affected areas. All of the species listed below supported mycelium of the fungus, although not all were killed. In many cases part of the root system of a plant was killed, but the remaining part was able to support the individual plant. Only those species clearly parasitized by the fungus are listed in the table. Since only a limited examination of these river courses has been made, it is very possible that more species can be added to the list.

Hosts for Rhizoctonia crocorum

Ambrosia aptera DC.
Diapedium brachiatum (Pursh) Kuntze
Malvaviscus drummondii T. & G.
Melia azedarach L.
Morus sp.
Parthenocissus quinquefolia (L.) Planch.
Phytolacca decandra L.
Rhus radicans L.
Rulac texana (Pax) Small
Salix nigra Marsh.
Sambucus canadensis L.
Smilax bona-nox L.
Solanum elaeagnifolium Cav.
Verbesina virginica L.
Viola missouriensis Greene

[1] Presented at the 1930 meeting of the Southwestern Division of the American Association for the Advancement of Science and published with the approval of the Director as Contribution No. 125, Technical Series, Texas Agricultural Experiment Station.

[2] Specimens of *Helicobasidium purpureum* (Tul.) Pat., the perfect stage of this fungus, have been found in the same area since this article went to press.

FIG. 1. A. Wooded area along Little River showing a dense layer of partially defoliated American elder, *Sambucus canadensis*, and common pokeberry, *Phytolacca decandra*. Violet root rot was found seriously affecting these and other species in this area. B. Area just above stream bed of Leon River showing dense stand of black willow, *Salix nigra*. Violet root rot was killing roots of willow in the area without causing death of affected trees.

In the areas with abundant moisture the fungus was prevalent on roots in the first 4 to 6 inches of soil. In one dry area at the edge of a cultivated field the fungus was not present on roots near the surface, although the plants had died. On digging to a depth of 16 to 20 inches mycelium was found in abundance. This would indicate that the fungus parasite is favored by ample moisture.

Examination of the Plant Disease Survey records does not show previous reports of the violet root-rot disease in Texas, and specimens of several species sent to the Office of Mycology and Disease Survey were reported to be new records for the United States.

PHYTOPATHOLOGICAL NOTES

Additional data on the range and prevalence of Lima-bean scab.—Mexico is to be added to the known geographic range of scab of the Lima bean, formerly reported[1] on this host only in Cuba and Porto Rico. Such distribution of the disease is shown by a number of specimens of green unshelled Lima beans referred to the writer for verification of the diagnosis by officers of the United States Plant Quarantine and Control Administration and taken by inspectors of the Administration, from Mexican shipments entering the United States at Nogales, Arizona, in January and February, 1931. The shipments were said to be from Caimanero, La Cruz, Rosales, and San Blas, in the department of Sinaloa. On the whole, the lesions on the Mexican specimens are smaller and less mature than on those intercepted from Cuban shipments received in New York during the same period, this year, and are suggestive of the younger lesions on pods from Cuba received early in the shipping season, which began in November. The continued prevalence of the disease in Cuban commercial fields is indicated by the infected pods, from occasional shipments, that have been deposited in the Office of Mycology and Plant Disease Survey of the Bureau of Plant Industry. For reference here it may be stated that during the past fiscal year 2,998,644 pounds of green unshelled Lima beans were imported into the United States from Cuba, 269,627 pounds from Mexico, and a much smaller amount (18 hampers) from Porto Rico.[2] For the present, at least, the pathogene of this disease is identified as *Elsinoe canavaline* Rac.[3] —Anna E. Jenkins, Bureau of Plant Industry, Washington, D. C.

Color variations in Aplanobacter michiganense.—A white strain of the normally yellow organism, *Aplanobacter michiganense*, the cause of bacterial canker of tomatoes, was reported by the writer in 1929. A second color variant has recently appeared, this time directly from bird's-eye spots on green tomato fruit, identically like those produced by the yellow and white strains of *A. michiganense*. This variant is shell pink, becoming salmon, on Thaxter's potato-dextrose agar; apricot buff on beef agar and potato cylinders. It produces fruit spot and wilt of the tomato typical for *A. michiganense* and is pink on reisolation from such lesions. It is less virulent than the yellow strain; is nonmotile and Gram-positive. Comparative work on the three strains is in progress.—Mary K. Bryan, Bureau of Plant Industry, Washington, D. C.

[1] Jenkins, A. E. Lima-bean scab caused by Elsinoe. Jour. Agr. Res. 42: 13–23. 1931.

[2] United States Department of Agriculture, Report of the Chief of the Plant Quarantine and Control Administration, August 15, 1930.

[3] *Loc. cit.* See footnote 1.

REPORT OF THE TWENTY-SECOND ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

THE CLEVELAND MEETING

The American Phytopathological Society held its twenty-second annual meeting from December 30th, 1930, to January 1, 1931, with an attendance of about 200.

The 83 papers delivered before the Society's several sessions may be grouped as follows: General and invitation papers, 4; vegetable diseases, 22; cereal diseases, 20; fruit diseases, 10; tobacco diseases, 6; diseases of miscellaneous crops, 21. Full abstracts of most of the papers presented at this meeting appeared in PHYTOPATHOLOGY for January, 1931.

Two joint sessions were held, one with Section G of the American Association for the Advancement of Science and the other—designated as the Heinrich Anton de Bary (1831–1888) Centenary Memorial program—with the mycological section of the Botanical Society of America. A special session was held on extension work in plant pathology, with special emphasis on methods and agencies used in reaching the people. The last part of the session on tobacco diseases was devoted to discussion of symptoms, diagnosis, and control of these diseases, and several of those in attendance presented specimens, photographs, and stereopticon slides.

Approximately 221 pathologists and their friends assembled for their annual dinner on Tuesday evening. Retiring-President H. S. Fawcett introduced W. H. Weston, Jr., as toastmaster. A selection of songs and several "stunts" were followed by a discussion of the proposed gift to the Imperial Mycological Institute in recognition of the work of E. J. Butler and his associates, by L. R. Jones, Donald Reddick, and others. Motion pictures portraying agricultural activities in the Union of Socialistic Soviet Republics, exhibited by J. G. Dickson, concluded the dinner program.

OFFICERS AND REPRESENTATIVES

The following officers were chosen:

President, M. W. Gardner, Purdue University Agricultural Experiment Station, La Fayette, Ind.

Vice-President, L. M. Massey, Cornell University, Ithaca, N. Y.

Councilor, G. W. Keitt, University of Wisconsin, Madison, Wis.

Associate Editors (three years), Charles Drechsler, U. S. Department of Agriculture, Washington, D. C.; G. L. Peltier, College of Agriculture, University of Nebraska, Lincoln, Nebr.; L. O. Kunkel, Boyce Thompson Institute for Plant Research, Inc., Yonkers, N. Y.; and F. D. Heald, State College of Washington, Pullman, Wash.

Business Manager (one year), F. C. Meier, Bureau of Plant Industry, Washington, D. C.

Advertising Manager (one year), J. F. Adams, Agricultural Experiment Station, Newark, Del.

Representatives on the Council of the American Association for the Advancement of Science (one year), D. Reddick, Cornell University, Ithaca, N. Y.; and C. W. Edgerton, Louisiana Agricultural Experiment Station, Baton Rouge, La.

Member of the Board of Governors of the Crop Protection Institute (three years), J. F. Adams, Agricultural Experiment Station, Newark, Del.

Elector to Assist in Naming a Group Representative for Group V, Division of Biology and Agriculture, National Research Council (three years), A. J. Riker, Uni-

versity of Wisconsin, Madison, Wis., alternate, John W. Roberts, U. S. Department of Agriculture, Washington, D. C.; Representative on the Committee of the American Type-Culture Collection (term 3 years, beginning Jan., 1929), C. L. Shear; Representative on Editorial Board of the American Journal of Botany, B. O. Dodge; Representative on the Committee on Cooperation with the Board of Editors of Biological Abstracts, H. P. Barss.

The following temporary committees were appointed to serve throughout the meetings:

Auditing Committee, R. S. Kirby and Donald Folsom.

Committee on Elections, J. S. Wiant, H. T. Cook, and J. A. Trumbower.

Committee on Resolutions, H. W. Anderson, R. E. Smith, and G. W. Keitt.

REPORT OF THE SECRETARY-TREASURER, 1930

The Society now has 747 members in good standing. We have 173 life members—86 paying currently and 87 paid in full—and 574 annual regular members.

During the past year we have lost 58 members and one has been reinstated. Of the 58 lost, 39 have been suspended for nonpayment of dues, 13 have resigned, and 5 have died.

There are 81 applications for new members and, if these are elected, this will bring our membership up to 828. New York leads with 14 applications and Wisconsin follows with 6. It is interesting to note that there are 14 applications from Japan and 3 from India.

STATEMENT OF ACCOUNTS FOR 1930, AS OF DECEMBER 17, 1930

Receipts:

Balance from 1929			$2,702.28
Annual dues: 1925	$ 10.00	(life)	
1926	10.00	(life)	
1927	10.00	(life)	
1928	22.00	($ 10 life)	
1929	41.75		
1930	1,790.22	($260 life)	
1931	2,314.13	($610 life)	
1932	12.40	($ 10 life)	
1933	10.00	(life)	4,220.50
Interest on checking account			44.83
Donations to Lyman Memorial Fund received with dues			11.00
Excess dues			.50
Sales received with checks for dues			2.90
Refund for photos of Des Moines meeting			1.50
Typing list of members for Dr. Schaffnit			4.70
Butler Fund donation received with dues			.50
Total receipts			$6,988.71

Expenditures:

Member subscriptions transferred to PHYTOPATHOLOGY (1930)	$1,500.00
Transferred to PHYTOPATHOLOGY for Sinking Fund	1,374.00
Secretarial work	543.70
Expenses of Secretary-Treasurer at Des Moines meeting	24.89
Postage and printed stamped envelopes	123.83

Printing (abstracts, menus, letterheads, preliminary announcements, application and nomination blanks, bills)		124.73	
Telephone and telegraph		15.17	
Office supplies		4.27	
Stencils and envelopes for press service		8.55	
Checks returned by bank		25.00	
Charges for collection of checks		1.40	
Donations transferred to Lyman Memorial Fund		6.00	
Donations transferred to Butler Fund ($1.00 not yet dep.)		1.50	
Sales transferred to PHYTOPATHOLOGY		.60	
Photos of Des Moines meeting		1.50	
National Research Council Yearbook		1.00	
Eriksson Prize and fee		50.50	
Balance as shown by bank statement attached		3,182.07	
			$6,988.71

SUPPLEMENTARY STATEMENT

Balance as above stated		$3,182.07	
Plus:			
Estimated income for 1931:			
From annual regular members	$280.00		
From life-sustaining members	27.00		
Interest on checking account	45.00		
	$352.00	352.00	$3,534.07
Less:			
Amount due PHYTOPATHOLOGY:			
For member subscriptions, 1930	766.00		
1931	1,607.30		
Other years	44.92	2,418.22	
Due Sinking Fund ($6.00 per life member):			
1925, 1926, 1927, 1928	24.00		
1930	12.00		
1931[1]	366.00	402.00	2,820.22
Total estimated income for 1931			$ 713.85
Based on 1930 expenses, expenses for 1931 (excluding Sinking Fund and member dues to PHYTOPATHOLOGY) will be			952.50
This would leave a deficit of			$ 238.65

During the past year, of the $10.00 paid by each life member, $6.00 has been transferred to the Sinking Fund and $4.00 to PHYTOPATHOLOGY, leaving none of the income from the life-sustaining members' payments for working funds for the Society. It is evident that a new allotment of funds must be made, both in the case of payments of life members and annual members.

Respectfully submitted,

F. C. MEIER, *Secretary-Treasurer.*

[1] As a result of action of the Council the amount to be credited to the Sinking Fund for 1931 will be $5.00 for each life-sustaining membership payment instead of $6.00 as indicated above.

REPORT OF THE BUSINESS MANAGER OF PHYTOPATHOLOGY FOR 1930

STATEMENT OF ACCOUNTS FOR 1930, AS OF DECEMBER 17, 1930

Receipts:

Balance from 1929		$ 487.14	
Subscriptions, 1930		2,503.39	
Subscriptions, 1931		904.29	
Subscriptions, other years		178.79	
Sales of back volumes and numbers		625.16	
Sales, Phytopathological Classics		.42	
Advertising, 1929		98.31	
Advertising, 1930		981.47	
Interest on Sinking Fund		376.75	
Donation from National Academy of Sciences		500.00	
Member subscriptions for 1930 (part)		1,500.00	
Transferred from Am. Phytopath. Soc. for Sinking Fund ($6.00 of each life-sustaining-member payment)		1,374.00	
Principal paid on first-mortgage notes		750.00	
Boyce Thompson Institute, cost of Wilcoxon-McCallan article		192.18	
State College of Washington, cost of cuts in Kienholz-Heald article		31.49	
Member dues received with subscription		5.00	$10,508.39

Expenditures:

Manufacturing PHYTOPATHOLOGY:				
Vol. XIX, No. 12	$528.48			
Vol. XIX, Index	149.47	$ 677.95		
Vol. XX, No. 1	789.84			
No. 2	343.73			
No. 3	371.87			
No. 4	552.84			
No. 5	629.52			
No. 6	340.31			
No. 7	375.04			
No. 8	491.77			
No. 9	401.16			
No. 10	505.60			
No. 11	372.52			
Vol. XX, Cuts	639.25			
Postage	404.32	6,217.77		
		$6,895.72	$6,895.72	
Secretarial work			87.75	
Expenses of Editor in Chief			81.90	
Subscriptions refunded			29.91	
Postage			16.66	
Expenses of Advertising Manager			173.27	
Sinking Fund invested			2,017.17	
Mailing lists			8.00	
Foreign draft and check returned			63.00	
Supplies ($23.85); printing bills ($17.40)			41.25	

U. S. Beet Sugar for error in remittance	10.50	
Balance shown by bank statement attached	1,083.26	$10,508.39

Last year our cash balance in the PHYTOPATHOLOGY account was $487.14, this year it is $1,083.26, of which $124.00 belongs to the Sinking Fund. We have paid for eleven numbers of the 1930 Journal and in so doing have not used $766.00 of the amount due from the Society for 1930 member subscriptions. The expenses of the December number and Index will be approximately $750.00 and the commission allowed the Advertising Manager and his secretarial work amounts to $128.57. Thus, a small amount of 1930 expenses will have to come from 1931 receipts, but the amount is much smaller than last year, showing that the financial condition of PHYTOPATHOLOGY is better than it was a year ago.

Much credit is due to Dr. H. B. Humphrey, Editor in Chief, for this improvement in the financial situation of the Journal. By limiting the number of printed pages, cost of publication has been reduced and at the same time a high standard of excellence has been maintained.

SINKING FUND

The Sinking Fund composed of six dollars for each sustaining life membership is now $7,026.00, of which $6,500.00 is invested in first-mortgage notes. Of the remaining $526.00, $402.00 is in the Society's checking account and $124.00 is in PHYTOPATHOLOGY'S checking account.

ENDOWMENT FUND

The endowment fund, established and named for Dr. George Richard Lyman, now totals $1,837.49 in cash donations and pledges, not including 8 pledges of indefinite duration, ranging from $1.00 to $25.00 annually and totaling $75.00 annually. Of this amount, $1,310.49 is placed in a savings account with the McLachlen Banking Corporation. The endowment-fund luncheon, arranged by the Iowa group during the 1929 meeting, added $219.00. During the year one member contributed his first fee received from professional services as a plant pathologist. The large number of member contributors is a convincing expression of faith in the future of PHYTOPATHOLOGY.

STATUS OF SUBSCRIBERS

Our edition of PHYTOPATHOLOGY is 1,625, of which 1,251 copies are mailed to members and subscribers. The number of subscribers in good standing at the close of 1930 is 500, of which 173 are domestic and 327 foreign. The number of subscribers has increased by only two this year. This is largely due to the loss of a number of subscribers from Japan and Russia.

Respectfully submitted,

F. C. MEIER, *Business Manager.*

REPORT OF THE EDITOR IN CHIEF

Throughout the year 1930 the members of the editorial staff of PHYTOPATHOLOGY have sought to improve the general excellence of our Journal. Closer and more critical attention has been given to the quality and scientific interest of the subject matter presented in each manuscript; a more rigid requirement has been set up and maintained governing the character and presentation of illustrative materials accompanying each contribution; and the Journal has held with general consistency to the policy of accepting only those manuscripts that pertain to plant pathology. Papers of a strictly taxonomic nature have been submitted for publication in PHYTOPATHOLOGY but have not been accepted.

The 20th volume of PHYTOPATHOLOGY comprises 1,011 pages of printed matter and illustrations, classified as follows: Eighty-seven articles, 26 phytopathological notes, 3 reports, the constitution of The American Phytopathological Society, 4 book reviews, 119 abstracts, 1 plate, and 185 text figures. From January 1 to December 31, 1930, approximately 131 manuscripts of articles, reports, book reviews, etc., and 86 manuscripts of abstracts were submitted. Of this number, 21 were returned to their authors for revision, 10 were rejected, and 3 were withdrawn by their authors. Of the several manuscripts received during 1930, 20 articles, 2 phytopathological notes, 1 book review, 84 abstracts, and 2 abstracts by title only are in press. About 30 per cent of the papers, exclusive of abstracts, presented in volume 20 of PHYTOPATHOLOGY were contributed solely or in part by employees of the United States Department of Agriculture.

The editorial staff earnestly solicits the cooperation of all, who submit manuscripts for publication in our Journal, in presenting the subject matter of their papers in accordance with a carefully organized outline in which first things come first and in which tables and illustrations are accompanied by suitable and adequate legends. More attention should be given to paragraphing one's subject matter, and the sense of each paragraph should be made immediately available to the reader the moment he has read its first sentence. We must still urge greater care on the part of our contributors in the selection and use of only the very best illustrations. Too many photographs are mere blobs which, when reproduced, show only vaguely or not at all the details the author fondly hopes may be revealed. Another thing we would urge upon our contributors: In all manuscripts accompanied by illustrations, the latter should not be sent loose in an envelope but should be arranged or mounted, by the author, in something like the order in which he wishes them to appear in the published paper. Too much of such detail is left to the editor. Manuscripts in excess of 60 pages are not to be encouraged, though if of exceptional quality longer ones will be accepted.

It is desirable that our journal become more and more truly international in its service. To further its progress in attaining such an aim, contributors who do not write in English are encouraged to submit manuscripts, preferably in German or French, accompanied by a comprehensive resumé in English.

The editor wishes here to express due acknowledgment of his appreciation of the excellent workmanship and spirit of cooperation shown by The Science Press Printing Company in maintaining the mechanical and editorial standards of excellence which characterize our Journal. Greater effort, however, is still necessary if we are to get each month's issue into the mail bags by the first of the month.

Thanks also are due J. Marion Shull for his expert aid in arranging and lettering the illustrative material and to Frances W. Todd for her invaluable clerical and editorial service.

H. B. HUMPHREY, *Editor.*

REPORT OF THE ADVERTISING MANAGER

The advertising returns show a slight increase over those received last year. For the twelve issues of PHYTOPATHOLOGY published during the year 1930, there appeared a total of 119 advertisements distributed as follows: 47 one-page, 43 one-half-page, and 29 one-fourth-page advertisements. The total advertising was equivalent to 75¾ pages, or an increase over last year of 6⅜ pages.

The renewal of contracts for 1931 at this time shows a decrease compared with the last five years. Soliciting for renewal of contracts is started in September and there appear to be considerable reductions in advertising budgets for 1931, as indicated by many old-line companies in failing to renew their contracts at this time. This may

be anticipated because of the general business depression and retrenchment. However, this is the time that greater cooperation of members is essential if we expect to maintain a reasonable advertising business. This past year only one member in the entire organization wrote the advertising manager relative to a prospect.

It is suggested that members write the advertising manager of any favorable prospects and, whenever in touch with commercial representatives, mention the opportunity PHYTOPATHOLOGY offers as a practical medium for advertising equipment and materials directly to the members with whom they wish to do business.

J. F. ADAMS, *Advertising Manager.*

COMMITTEE ON INVESTIGATION OF FOREIGN PESTS AND PLANT DISEASES

During the past year this committee has continued its activities in connection with furthering studies on plant pests and diseases in foreign countries. We are fully convinced that such studies by specialists from our own nation constitute the most logical approach to the problems concerned with dangerous parasites that are likely to be introduced at any time from foreign lands.

With the cooperation of Dr. J. H. Faull, we have supplied Dr. Westerdijk at the Phytopathologisch Laboratorium at Baarn, Holland, with species of American elms to be tested for their resistance to the Dutch elm disease and have been informed that our common *Ulmus americana* is very susceptible. Reports on other species will be forthcoming.

Our efforts to secure provisions for the permanent recognition of this work, by the insertion of an item in the Congressional Budget, are being continued in cooperation with the Society of Economic Entomology. We are assured that our recommendations are being given serious consideration and that already the joint resolutions of the organized phytopathologists and entomologists have been influential in the decision of Federal officials to approve the expenditures necessary to send specialists to foreign countries for such special purposes as securing parasites of the Mediterranean fruit fly, the Japanese and Asiatic beetles, Citrus black fly, and the corn borer, as well as for investigations on cereal and other diseases.

As additions to the previous list of dangerous plant diseases which should be investigated, we would add the Mal Secco disease of lemons which occurs in the Mediterranean region, the Bayond disease of the date palm in Morocco and Algeria, and the Elsinoë disease of beans in Cuba, the latter having been intercepted several times at our ports of entry.

C. R. ORTON, *Chairman,*
W. A. MCCUBBIN,
F. D. FROMME.

COMMITTEE ON QUARANTINE AND REGULATORY WORK

1. Your committee would call the attention of this body to the growing need for thoughtful consideration of many important and perplexing problems in the field of State and Federal quarantine and regulatory work and would urge upon the Society as a whole and upon the membership individually a wider and deeper interest in these problems, to the end that we may more completely fulfill our whole professional duty to the public interest.

In this connection the committee ventures to suggest that the Society give due consideration to the policy of including in each year's program some feature dealing with the quarantine and regulatory aspects of plant pathology. And, further, that a place be made from time to time in PHYTOPATHOLOGY for articles of outstanding interest and importance on these matters.

2. The committee presents for your consideration the following resolution:

"This Society believes that the success or failure of State or Federal action against sudden outbreaks of plant disease is often determined by the promtpness with which suppressive or restrictive measures can be fully employed, as well as by the rapidity with which the essential elements of these problems can be ascertained.

"This Society, therefore, declares itself in favor of an 'Emergency policy' involving (1) an emergency fund, protected by suitable safeguards and available only for emergency purposes; (2) arrangements whereby rapid and adequate surveys can be made on short notice; and (3) provision for such immediate research as will develop the information necessary for intelligent action."

We move that this resolution be adopted and that copies of the same be sent to the Secretary of Agriculture, the Plant Quarantine and Control Administration, the National Plant Board, and the Society of Economic Entomologists.

W. A. MCCUBBIN, *Chairman*,
MAX W. GARDNER,
J. F. ADAMS.

COMMITTEE ON EDITING PHYTOPATHOLOGICAL ABSTRACTS

The committee on editing the abstracts submitted for presentation at the annual meeting regards its position as intermediate between two extreme views which have been voiced or tacitly assumed by the Society membership: (1) Some hold that the contributions made by these abstracts are either of minor importance, embodying incomplete or incidental work, or, if they contain really new and significant material, they will later be published in full and the Society is not warranted in standing the expense of duplicate publication; there are also some who attach much less importance to these abstracts than they do to the publication of a complete paper and even take rather lightly the responsibility assumed in making a contribution to scientific literature in this way. (2) Others frankly hold that the Society needs a clearing house, functioning at least annually, for the numerous miscellaneous items that interest the members of the Society during the course of a year's work, so that priority may be promptly established for a novel idea or so that the results of their work may at once be put into circulation.

These questions have been discussed at length and often with warmth in previous meetings of the Society. For the benefit of novitiates of the membership, as well as others who may have forgotten the past, the present arrangement of having all abstracts submitted to careful editorial scrutiny grew out of the arguments for and against the publishing of abstracts at the Toronto meeting in 1922. Because of the extra work involved, a committee is appointed to perform this duty instead of assigning it to the editor of PHYTOPATHOLOGY, but the committee works in close cooperation with the editor.

Out of the experience of reviewing a hundred abstracts each year for the past eight years, this committee has seen the need for correcting certain tendencies in the preparation of the abstracts, such, for example, as tardy submissions; prolixity; ambiguity, especially in titles; and disproportionate use by different members of this privilege of immediate publication. They also have proposed certain rules governing the submission of abstracts which have been voted upon and accepted by the Society. These rules ought to be consulted and observed by all who present abstracts and, beginning with this year, they are being published in the preliminary announcement of the annual meetings.

When, occasionally, it becomes necessary to invoke these rules and reject an abstract or in other ways restrict the privilege of publication, the members concerned should

realize that the action taken is approved by a majority of, and usually by the entire, committee, after consultation with the editor and the secretary of the Society.

Usually only the defects of an abstract, and not all of them, are susceptible to legislative correction; the virtues can be pointed out and extolled but not prescribed for general adoption. The abstracts this year have been the best as regards submission, conformity to the 200-word limit, substance, and manner of presentation, that this committee has seen. It is felt that no further modification of the rules is necessary. However, a few recommendations are offered which may help authors to avoid the sort of defects that can not be corrected by legislation. These follow:

Historical reviews of literature, however pertinent to the new findings, are to be avoided. In nearly all cases an appropriate statement of the new findings will in itself tacitly put these findings into a sufficiently clear relationship to the body of knowledge already extant, pending more complete elaboration in a lengthy paper.

Expressions of opinion as to what constitutes a point of interest, of importance, or of significance, either general or specific, are to be avoided. Efforts at evaluation, while highly appropriate for lengthy publications in which the ramifying implication of a new fact can be adequately dealt with, when attempted in a bold remark or in a number of flattering adjectives, very often convey only a somewhat exaggerated notion of the writer's immodesty. An appropriate statement of new findings should in itself express or imply both the measure of importance and the quality of interest attaching to those findings.

References to work under way but, not at the time of writing, productive of significant results are to be avoided. Even more rigorously to be shunned are references to work not yet begun but contemplated in the future, as well as prophetic remarks concerning the profitableness of this or that line of investigation.

FREEMAN WEISS, *Chairman*,
J. W. ROBERTS,
ANNIE R. GRAVATT,
CHARLES DRECHSLER,
W. A. WHITNEY.

COMMITTEE ON INTERNATIONAL RELATIONS

Following thorough consideration at the Des Moines meeting of plans looking to a closer union of workers in the field of plant pathology, your committee sent copies of the tentative plan, adopted in principle, to as many pathologists as possible in other countries. The response was so cordial that the organizers of the Cambridge meeting of botanists were asked for the privilege of bringing the subject forward for consideration at a formal session of the section My, Mycology and Plant Pathology, of the Fifth International Botanical Congress.

At an informal conference at which at least 50 persons, representing perhaps half as many nations, were present, a discussion similar to that at Des Moines was held in which substantially the same conclusions were reached, namely, that plant pathology should have autonomy within the Botanical Congress and that some more formal international organization than now exists is needed. At the formal session the proposal of The American Phytopathological Society was presented, whereupon three resolutions were adopted, the first two of which were forwarded to the organizers of the Sixth Congress which is to be held in Holland.

1. That at the Sixth International Botanical Congress, plant pathology be given full sectional autonomy.
2. That at the Sixth International Botanical Congress, mycology be given full sectional autonomy.

3. That an international standing committee be appointed to deal with urgent phytopathological needs that may arise between the Fifth and Sixth International Botanical Congresses.

This resolution was adopted in the section My. It was sent to the plenary session of the Congress, proposed by Appel, seconded by E. Van Slogteren, and adopted. The officers of the section My appointed on the standing committee E. J. Butler and Donald Reddick (Recorder) and gave them power to co-opt members.

An international council of plant pathology is thus established to serve a probationary period of 5 years. Obviously, the number and the nature of the problems which are presented to this committee will be instrumental in determining the necessity for its continuance. It is too much to expect that the committee will of its own initiative search for work to do. The problems of international importance which individuals lay before the committee will receive attention from a group duly constituted for that purpose.

A committee designated by The American Phytopathological Society should be continued for the purpose of acting in an advisory capacity to the American representative on the international committee.

R. J. HASKELL, *Chairman*
G. H. COONS,
H. S. FAWCETT,
H. S. JACKSON,
DONALD REDDICK,
J. C. WALKER.

COMMITTEE ON PRESS

Following the plan inaugurated for a more adequate coverage of the Des Moines meetings, the Press Service again prepared paper-by-paper accounts of the Society's several sessions and released to over ninety papers, magazines, and press associations a 29-page mimeographed sheaf of stories based on the abstracts of the meetings.

While the Press Service has no way of determining the use to which the releases were put, information received from time to time indicates that the service has been of value both to the recipients of the material and to the Society. Plans are under way, even at this early date, for the betterment of the material to be released for the coming New Orleans meeting. In this connection, the chairman wishes to express his grateful thanks to Mr. Don B. Reed, day city editor of the *Washington Post*, and other members of journalistic profession for their valuable criticisms and suggestions.

The chairman also wishes to acknowledge his indebtedness to F. C. Meier, Dr. W. J. Zaumeyer, and others for their kind cooperation in assembling and mailing the 1930 releases.

The report published (Science, n. s. 73 (1884): 156–157, 1931) of the twenty-second annual meeting of the Society was prepared by the Press Service.

To the membership of the Society the Press Service makes an urgent plea—not only for itself, but for the Committee on Editing Phytopathological Abstracts (of which, also, the chairman is a member)—for a greater amount of information in submitted abstracts. Those of the past year were the best yet submitted; yet there is room for a vast improvement, for there are still many abstracts from which, to obtain a news story, the Press Service has to draw on its professional knowledge. To fulfill its aim—to present in a form comprehensible to the newspaper reader the facts and discoveries of phytopathology—the cooperation of the Society in preparation of adequate abstracts is requested.

W. A. WHITNEY, *Chairman.*

COMMITTEE ON NECROLOGY

During the calendar year 1929, there was one death not included in the previous report, namely that of Mr. Maturin Livingston Delafield, who died December 18, 1929.

During the calendar year 1930, there have been three deaths as follows:

Dr. William Allen Orton, died January 7, 1930.

Mr. Emil Godfred Arzberger, died January 29, 1930.

Dr. Nathaniel Orson Howard, died September 14, 1930.

A. G. JOHNSON, *Chairman*,
G. P. CLINTON,
M. B. WAITE.

REPORTS OF OTHER COMMITTEES AND REPRESENTATIVES

Report of Activities of the Division of Biology and Agriculture of the National Research Council. The present year marks the end of the three-year period during which the writer has served as the representative of Group 5 of the Division of Biology and Agriculture. Group 5 includes The American Phytopathological Society and the Society of American Bacteriologists. During the latter two years your representative has also served on the Executive Committee of the Division. In all, some ten or twelve meetings of the Division and of the Executive Committee have been attended within the three-year period. According to the plan of organization, Group 5 will be represented during the next three-year period by an elector nominated by the Society of American Bacteriologists, while the elector from The American Phytopathological Society will serve as alternate.

The work of the Division is accomplished largely through its committees and affiliated organizations. Some twenty committees have been active during the present year. A complete report of the activities of the Division is prepared by the chairman and is included in the report of the National Research Council. The following items may be noted as of particular interest to The American Phytopathological Society:

The Committee on the Effects of Radiation upon Living Organisms has secured funds from private sources for investigations in this field and during the current year has allotted a total of $22,850 to twenty-three investigators. A very large amount of apparatus also has been secured either as loans or as donations to investigators. A general survey of the field looking toward the development of a broad study of radiation is now under way through seven advisory groups each of which is considered a special division of the field.

The Committee on Infectious Abortion has established a central station at the Michigan State College for the study of the causal organisms of infectious abortion and undulant fever. The work is made possible through gifts from the Commonwealth Fund and from other sources.

A Committee on Microbiology of the Soil has been organized during the year.

Publications resulting from the work of committees include a bulletin of the National Research Council entitled "Weather and Health," which is an outgrowth of the work of the Committee on the Atmosphere and Man; a booklet entitled "Volume, Yield, and Stand Tables for Second-growth Southern Pines," by the U. S. Department of Agriculture, is the outcome of the work of the Committee on Forestry, which also has under way a compilation of the forestry literature of North America, which will include about 50,000 titles; a list of wild drug plants issued by the Committee on Pharmacognosy and Pharmaceutical Botany; and a second edition of "Biological Stains" has been issued by the Commission on the Standardization of Biological Stains. The book entitled "Plant Rusts," by Dr. J. C. Arthur and others, which was sponsored in part

by the Division, has also been published. The preparation of a series of bibliographies in the biological sciences is under consideration by the Director of the Research Information Service of the National Research Council.

Funds available for fellowships in the biological sciences have been increased and the scope has been broadened to include agriculture and forestry. A total of seventy-two appointments has been made for the coming year. Considerable assistance to research in the natural and physical sciences has been available since 1929 through a special fund of $100,000, administered by the National Research Council. A total in excess of $75,000 has so far been distributed in ninety-six separate grants. Of these, sixteen were for projects in the biological sciences. A portion of the fund has been set aside for the support of projects of a general nature which may be utilized for the calling of conferences on specific problems or fields of research.

F. D. FROMME,
Representative of the American Phytopathological Society and the Society of American Bacteriologists.

Committee on American Type Culture Collection.

Number of cultures on hand January 8, 1930	501
Number of cultures on hand December 18, 1930	654
Number of cultures sent to headquarters at Chicago during the year	219

Our facilities for handling cultures have been increased during the year by the addition of a General Electric refrigerator of 13 cubic feet capacity, in which a temperature of 8° C. is maintained. We have also another refrigerator in which a duplicate set of all cultures is stored at a temperature of 5–6° C. Keeping the stock cultures at these low temperatures greatly reduces the labor and expense of transferring them.

C. L. SHEAR,
Representing the American Phytopathological Society.

Tropical Plant Research Foundation. As is, of course, well known to the members of our Society, the Foundation suffered an irreparable loss in the death of its director, Dr. W. A. Orton, on January 7, 1930. This was the more serious, since, at this time, there is much depression in all phases of the plant-production activities of the Latin-American countries. Since this is a part of the world-wide situation, it is impossible to foresee the outcome for the immediate future. One of the very serious phases of this involves the sugar industry, with which the Foundation has had important relations and from which its chief support has been derived. Under the circumstances it has been necessary to await a more stabilized condition in these fields before we can proceed with assurance as to the reliability of the financial support of research projects in connection with organized industry. The Foundation therefore has not, up to this time, considered it expedient to seek to appoint a successor to Dr. Orton. Aside from this, the Foundation has maintained its organization intact and can report the satisfactory continuation of its activities so far as they relate to all projects now in progress.

L. R. JONES,
Representing the American Phytopathological Society.

The American Association for the Advancement of Science. A brief informal report of the representatives on the Council of the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE was presented by Donald Reddick.

Committee on Chicago "Century of Progress." The American Phytopathological Society, recognizing the unusual significance of Chicago's forthcoming Exposition, "The Century of Progress,"

And assured of the importance of the part which plant pathology—including the study of both cause and control of plant diseases—has played in the general development of plant sciences, and especially in the progress of scientific agriculture.

Authorizes and instructs its official representatives to offer the proper representatives of the Exposition the cooperation and services of this Society in all practical ways to the end that adequate exhibition be made of the progress and present status of this science.

L. R. JONES,
H. W. ANDERSON,
CHAS. GREGORY,
M. B. WAITE,
G. K. K. LINK.

Auditing Committee. We, the undersigned Auditing Committee, have examined the books of The American Phytopathological Society. The books were found in good order.

R. S. KIRBY,
DONALD FOLSOM.

Resolutions Committee. A committee consisting of G. W. Keitt, Ralph E. Smith, and H. W. Anderson, brought in the following report, which was adopted by the Society.

Resolved: That the members of The American Phytopathological Society extend their sincere thanks to the members of the local committee on arrangements, especially to Professor Visscher and Dean Focke of the Case School of Engineering for their efficient efforts in contributing to the success of the Cleveland meeting.

Resolved: That the Society express its appreciation to Western Reserve University for the excellent facilities furnished for the Cleveland meeting of the Society.

Resolved: That the members of The American Phytopathological Society assembled at Cleveland, Ohio, extend to Miss Mary G. Van Meter their very sincere appreciation of her long and efficient service in the interests of the Society and their regrets that she has found it necessary to withdraw from this activity.

Resolved: That provision be made for a standing committee on extension work in plant pathology composed of five members selected by the Council.

ACTION OF THE COUNCIL

In addition to making the appointments mentioned in the first part of this report, the Council made the following recommendations, which were approved by the Society:

1. That, as was the case in 1930, the Editor of PHYTOPATHOLOGY be allowed actual expenses for 1931 up to or within $300.00 for secretarial and editorial assistance.

2. That the summer field trip in southern Indiana and Illinois, scheduled for 1930 but cancelled because of cold injury to fruit trees of that section, be held in 1931, and that the previously appointed committee, consisting of M. W. Gardner, H. W. Anderson, and Leslie Pierce, take charge of arrangements.

3. That the Secretary-Treasurer make allotment of life-membership funds as follows: $1.00 to the Society; $4.00 to the Journal, and $5.00 to the Sinking Fund.

4. In view of the fact that the Secretary-Treasurer has asked to be relieved of the sole responsibility for investment of Society funds, a temporary committee be appointed to advise with the Secretary-Treasurer as to best methods of accomplishing this service and report at the next annual meeting.

5. That the four new associate editors for this year be chosen by the Editor in Chief and Secretary-Treasurer.

OTHER BUSINESS

The Secretary read a letter from T. G. Major, Secretary-Treasurer of the Canadian Phytopathological Society, expressing hope for a successful meeting in Cleveland and naming the officers of that organization for 1931 as follows: President, W. P. Fraser; Vice-President, D. L. Bailey; Secretary-Treasurer, T. J. Major; and Councillors, H. T. Güssow and G. H. Berkeley. Dr. Major extended a cordial invitation to members of our Society to attend the next meeting of the Canadian Society at the Ontario Agricultural College, Guelph, Ont., about June 24 and 25.

The Secretary read a letter from Dr. M. P. Löhnis of Wageningen, Holland, addressed to Dr. L. R. Jones, in which she called attention to the fact that March 15, 1931, marks Dr. Johanna Westerdijk's 25th year as directress of the Laboratory Willie Commelin Scholton. A motion was made by Dr. Jones and carried that, in view of the fact that many of Dr. Westerdijk's friends would wish to write her on this occasion, the Secretary be instructed to provide for the assembling and sending of these letters.[2]

A letter, addressed to the Secretary by Dr. H. M. Quanjer, was read, in which he requested that our members be informed of the fact that the Eriksson Prize has been awarded to Dr. J. H. Craigie; also, that the jury for the virus-disease prize failed to reach a conclusion; consequently, 2,000 Swedish kroner will be reserved for the offering of new prizes at the International Botanical Congress scheduled for 1935 in Amsterdam. Dr. Quanjer expressed the hope that members of our Society will continue to show interest in this international undertaking.

It was moved by Dr. I. E. Melhus, and carried, that the members of the Council consider ways and means of publishing the papers presented in the de Bary Memorial Program as a separate and that, on reaching a decision, they have power to act.

A motion was made and carried that the Council draft a letter to Miss Mary G. Van Meter in recognition of her efficient service to the Society as assistant to the Secretary-Treasurer during the period May, 1922, to August, 1930.

[2] These letters were sent to Dr. Löhnis on February 24 for transmittal to Dr. Westerdijk.

WILLIAM ALLEN ORTON

FEBRUARY 28, 1877—JANUARY 7, 1930

William Allen Orton was graduated from the University of Vermont with the B.S. degree in 1897. He received the M.S. degree at the same institution in 1898, specializing in botany and plant pathology. In 1915 the degree of D.Sc. was conferred upon him also by the University of Vermont.

In June, 1899, Doctor Orton entered the United States Department of Agriculture, two years before the organization of the Bureau of Plant Industry, and for a little more than a quarter of a century was prominently associated in a constructive way with the activities of the Department. During the first decade he carried on researches on diseases that were causing serious losses to cotton, cowpeas, and watermelons. He was a pioneer in the breeding of varieties resistant to the widespread wilt and root-knot diseases of these crops. In 1907 he was made head of the Office of Cotton, Truck and Forage Crop Disease Investigations. Under his direction diseases of the important vegetable and forage crops received major attention. The infectious nature of potato-virus diseases was discovered, and methods of control through the use of certified seed were worked out. He also helped organize the now accepted methods of potato-seed certification. He organized the Plant Disease Survey work and with others started and carried on research on diseases causing losses to vegetables in transit, market, and storage. He was active in the work leading up to the passage of the Plant Quarantine Act, and, from 1912 to 1924, he was Vice Chairman of the Federal Horticultural Board.

He was one of the organizers of The American Phytopathological Society, its president in 1921, and the editor of PHYTOPATHOLOGY from 1916 to 1920, inclusive. He was a member of a large number of botanical, agricultural, and related organizations.

In 1924 he resigned from the Department, after 25 years of service, to become scientific director and general manager of the Tropical Plant Research Foundation and, during the last six years of his life, organized and carried forward important research projects relating to production and diseases of cotton, sugar-cane, chicle, and other tropical and subtropical crops.

Doctor Orton was the author of more than 100 papers, mostly on various phases of plant pathology and on diabetic dietaries. He was a man of unusually broad vision and clear judgment and possessed great original ability for the organization of research. He was always kindly, considerate of others, and of an even temperament; hence his circle of friends was great. In the words of one of his close associates, "He stood on an eminence apparently without realizing his own greatness. He was so friendly, so tolerant, so just, so modest with all, that it seems to me now we worked with a great man without then understanding his true greatness or the rare privilege of serving with him."

EMIL GODFRED ARZBERGER

OCTOBER 3, 1877—JANUARY 29, 1930

Emil Godfred Arzberger graduated from the State Normal School, Whitewater, Wisconsin, in 1903. In 1906, he received the degree of Ph.B. from the University of Wisconsin and, in 1910, he received the degree of M.A. from Washington University, St. Louis, Missouri.

From 1910 to 1913, he was Assistant Botanist at the Ohio Agricultural Experiment Station. During the summer of 1913, he was Research Fellow at the New York Botanical Garden. From the fall of 1913 to the time of his death Mr. Arzberger was Assistant Pathologist, Office of Nematology, Bureau of Plant Industry, U. S. Department of Agriculture.

Mr. Arzberger was a man of high ideals, sincerity, and integrity. He was a tireless, skillful worker in the field of botanical science, which he loved.

NATHANIEL ORSON HOWARD

MAY 11, 1880—SEPTEMBER 14, 1930

Nathaniel O. Howard received the degrees of Ph.B. in 1903, Sc.M. in 1917, and Ph.D. in 1925, all from Brown University. The Rhode Island College of Pharmacy granted him the degree of Pharmaceutical Chemist in 1929.

From 1905 to 1918, Dr. Howard taught chemistry at the Technical High School in Providence, R. I. After 1920 he was, for several years, part-time Instructor in the Department of Botany, Brown University. For several years he also taught botany at the Rhode Island School of Pharmacy. From 1913 to 1917, he worked part time on various problems in forest pathology, in connection with the Office of Forest Pathology, Bureau of Plant Industry, U. S. Department of Agriculture. From 1918 to the time of his death, he was employed practically full time in this connection.

Dr. Howard was of a quiet nature and a kindly disposition, a loyal friend, and cooperative associate, a thorough and beloved teacher, a devoted husband and father, a scientist of broad interests, and a thorough and careful investigator.